Open RAN Promotion Subcommittee Activity Report

March 2024

About the Open RAN Promotion Subcommittee

The Open RAN Promotion Subcommittee is an organization within the Beyond 5G Promotion Consortium. The Beyond 5G Promotion Consortium was established by members of the Beyond 5G Promotion Strategy Roundtable based on “Beyond 5G Promotion Strategy—Roadmap towards 6G—” published by the Ministry of Internal Affairs and Communications in June 2020. Through industry-academia-government collaboration, the Consortium is carrying out activities aiming at the early and smooth deployment of Beyond 5G and the enhancement of international competitiveness for Beyond 5G in order to realize the resilient and vibrant society expected in the 2030s.

The Beyond 5G Promotion Consortium consists of the General Meeting and its affiliated committees: The Committee for Planning and Strategy and the International Committee. The Committee for Planning and Strategy discusses the results of technical reviews of trends and elemental technologies in Japan, while the International Committee discusses the status of initiatives overseas. While the discussions in these committees progressed, there was no place in Japan for the flat and continuous exchange of views on Open RAN, which will be an important technology in Beyond 5G as well as in 5G, among major players in Japan and overseas. Therefore, consideration was started for the establishment of a subcommittee dedicated to it within the Beyond 5G Promotion Consortium. As a result, it was approved to establish the Open RAN Promotion Subcommittee under and jointly supervised by the Committee for Planning and Strategy and the International Committee. The Subcommittee was officially launched with the Open RAN Promotion Subcommittee Kickoff Event held on March 18, 2022.

The Open RAN Promotion Subcommittee is working to share information on, and discuss among a wide range of relevant parties in Japan and overseas, dissemination and deployment of open base stations in Japan and overseas, and test centers to verify the interconnectivity of open base stations. In the FY 2022, discussions were held to share initiatives and challenges among companies, as well as to explore strategies for the full-scale deployment of commercial networks. The outcomes of these discussions were compiled into the first edition of a report, which was published domestically and internationally in March 2023. Furthermore, insights obtained from the discussions of this subcommittee have contributed to the operations of "Japan OTIC," established in December 2022. This update presents the second edition of the report, incorporating revised content and findings.

Table of Contents

List of Figures

List of Tables

Abstract

As 5G services become widely used in earnest, mobile network operators (MNOs) around the world are increasingly using Open RAN, in which a Radio Access Network (RAN) is built among devices defined by open interfaces, in order to develop commercial 5G networks. MNOs, communication equipment vendors, and other various players are promoting Open RAN in businesses related to the development of new 5G networks. For such Open RAN, this report was prepared for the purpose of summarizing the status of initiatives for technology and business, changes from the past, changes in the business environment in each country, and expected effects in the future, and presenting ideas and policies for each player to contribute to the spread of open, secure, and transparent radio access networks both in Japan and overseas.

Chapter 1 summarizes the technological trends related to Open RAN from the perspectives of "Open," "Virtualization," and "Intelligent." "Open" indicates the architecture and connection interfaces that have been standardized in the O-RAN ALLIANCE. The opened RAN implements the "Virtualization" (cloud) infrastructure architecture with general-purpose servers equipped with accelerator functions that deliver performance comparable to that of conventional dedicated hardware, resulting in potential improvement of availability and scalability. "Intelligent" machine learning-based devices and traffic control are expected to result in reduction in operating costs in addition to increase in added value, such as flexibly meeting user needs. Moreover, high-quality and secure network services can be provided by developing technologies for security and low power consumption.

Chapter 2 introduces expectations, problems and initiatives for the spread of Open RAN from the perspective of players, including MNOs and vendors who play a main part in building networks, and users of the networks. From the perspective of MNOs, the chapter shows the status of studies and initiatives in the procurement, testing, and operation processes. There are expectations for an increase in choices of products that can be interconnected from environments that depend on specific vendors, technological advances associated with competition among companies, reduction in TCO through cost optimization, and supply chain stabilization. In addition, the realization of intelligence and virtualization is expected to improve quality in service delivery and provide new value added. From the vendors' point of view, the chapter summarizes the processes of design, development, testing, sales and deployment of commercial distribution. While there is a risk of decline in market share in existing markets, it has become clear that a new ecosystem could be built by efficiently developing products that take advantage of companies' own strengths and expanding the testing equipment markets. Furthermore, from the perspective of users who utilize the networks, the chapter mentions reduction in risks of service outage caused by supply chain and improvement of service levels resulting from initiatives by MNOs and vendors. Furthermore, regarding initiatives related to Open RAN, we will introduce the progress of efforts in various countries including Japan using specific examples. Over the past two to three years, the adoption of Open RAN has been confirmed worldwide, and it is currently in a phase of widespread proliferation. Japanese MNOs and vendors are actively pursuing initiatives for overseas expansion. Strategic activities, such as alliances and partnerships, are being carried out by each operator to gain initiative in this field.

Chapter 3 summarizes the moves toward standardization and overseas deployment of Open RAN from the perspectives of MNOs, vendors, and other companies, as well as from the perspective of the national government. While Japanese MNOs and communication equipment vendors are working on building cooperative relationships with overseas operators by establishing overseas bases, utilizing their in-house labs in Japan and overseas, and Japan OTIC, the national government lists "Open RAN centered 5G" as one of

the “10 priority areas requiring enhanced initiatives toward 2025.” In order to enhance the international competitiveness of Japanese companies, the national government has concluded bilateral memorandums of understanding with other countries, and is providing support for the establishment of environments to build a cooperative structure. In addition to reviewing the activities of the Open RAN Promotion Subcommittee, we will also discuss future necessary efforts aimed at further promoting the adoption of Open RAN and enhancing the competitiveness of Japanese companies.

1. Market trends surrounding Open RAN

5G, which is now commercially available, has two types: The non-standalone (NSA) architecture, which uses existing 4G LTE base stations, new 5G base stations, and 4G core networks (EPC); and the 5G Standalone (SA) architecture, which consists of 5G base stations and 5G core networks. Their respective network architectures are outlined in Figure 1-1. The components of a 5G network can be broadly divided into a Radio Access Network (RAN) consisting of terminals (UE), wireless base stations and controllers, and 5G Core Networks (5GC) or 4G Core Networks (EPC: Evolved Packet Core Network). For RAN, in which large capital investment is required to provide 5G services, vendors are actively carrying out initiatives to provide equipment and software used by MNOs and RAN.

RAN consists mainly of Radio Units (RU), which have functions to handle radio frequencies (RF) between antennas and terminals, Distributed Units (DU), which have several functions such as modulation and demodulation of digital signals, as well as encoding and decoding, and Central Units (CU), which control RU and DU and connect to the core network.

3GPP has defined the combination of functional divisions, i.e., which communication function of each layer, such as RF, PHY, MAC and RLC, is performed by RU, DU or CU, as options in the specifications. The configuration is that RU handling the RF or PHY layer and DU handling communication in the higher layers are separated, and a network called fronthaul is used to connect between them.

The Open Radio Access Network Alliance (O-RAN ALLIANCE) further separated DU into O-DU and O-RU, defined an open fronthaul as an interface between O-DU and O-RU, and published (opened) the functions and interfaces not defined as standards in 3GPP as the "O-RAN" specifications. "Open RAN" refers to open specifications of functions and interfaces connecting those functions, and "O-RAN" refers to the specifications defined by the O-RAN ALLIANCE in particular[1]. The opening enables interconnection among functions in a multi-vendor environment.

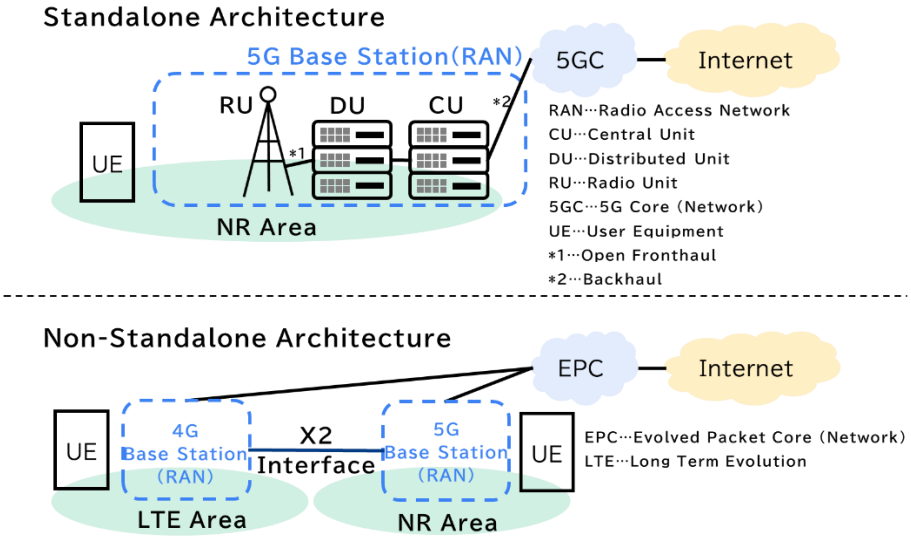

Figure 1-15G architecture

Source: Prepared by Mitsubishi Research Institute

The standardization by the O-RAN ALLIANCE is expected to make it easier for various vendors to provide

[1] O-RAN ALLIANCE, a standardizations organization, is also referred to as "O-RAN."

communication equipment, as well as make it easier to construct areas with flexible system configurations and reduce the time required to procure equipment. Today, there are a growing variety of needs regarding mobile networks, in addition to high speed, high capacity, and other traditional needs, such as the diversification of mobile applications including Multi-access Edge Computing (MEC), and environments in which many nodes are connected as a result of IoT systems that have been deployed in various environments. To meet these needs, it is necessary to be able to expand the network flexibly and quickly with less expense and labor. Thus, by opening interfaces between functions of the radio access network and virtualizing devices, MNOs can reduce the time to market because they only need to add or replace necessary functions or devices whenever necessary without replacing other connected devices. In addition, they can choose the optimal product from a variety of vendor products, reducing their dependence on particular vendors. Vendors can also have opportunities to enhance their competitiveness and to enter new markets.

1.1 Technological trends

O-RAN ALLIANCE and 3GPP are promoting technology standardization for the purpose of making RAN "Open," "Virtualization," and "Intelligent."[2] This section describes the requirements and technologies for realizing these purposes. The impacts of implementation of these requirements on quality and other factors were also examined.

1.1.1 Open

The standardization of connection interfaces between devices constituting RAN and the opening of software constituting RAN will enable MNOs to choose the optimal product from a variety of products that meet specifications for each function. In other words, they can break away from so-called vendor lock-in since they can procure and deploy devices and software that are not limited to existing vendor products.

As shown in Table 1-1 and Figure 1-2, the RAN architecture standardized by 3GPP and O-RAN ALLIANCE defines 9 network components including O-CU, O-DU, O-RU and O-Cloud (O-RAN Cloud Platform), which is the cloud environment running them, and 19 interfaces between the components as indicated by the green line in Figure 1-2. The specifications of the interfaces indicated by the black line (E1, F1, Xn, etc.) have been standardized in 3GPP. SMO (Service Management and Orchestration), a framework for monitoring, maintenance, and orchestration of RAN, and Non-Real Time RIC (RAN Intelligent Controller) and Near-Real Time RIC in SMO have been defined as functions deployed outside RAN.

The roles of several interfaces and components are as follows. The A1 interface for controlling RIC defined in Open RAN is used for communication between two types of RIC, and applies a machine learning (ML) model in Non-Real Time RIC to transfer analysis-based policy changes to Near-Real Time RIC and reflects them in the control of RAN. Near-RT RIC collects information on the E2 nodes (O-CU, O-DU, O-eNB (O-RAN eNB)) via the E2 interface and reflects it back to the control of the E2 nodes via the E2 interface based on the analysis results according to the given policies. The O1 and O2 interfaces connect SMO, which has the orchestration function, to other nodes, and collect information on each node and coordinating the whole. The open fronthaul is an interface connecting between O-DU and O-RU. The open fronthaul CUS-Plane allows synchronization between nodes, and the open fronthaul M-Plane allows SMO to manage O-RU and detect faults. The F1 interface connects between O-CU and O-DU and share frequency resource information.

[2] https://www.o-ran.org/who-we-are Retrieved on March 19, 2024

The X2 and Xn interfaces enable communication between different base stations. The specifications of interfaces that are optional under 3GPP and whose specifications had been defined separately for each company have also been defined by the O-RAN ALLIANCE by obtaining the agreement of companies, making it easier to connect devices under a multi-vendor environment.

The definition and publication of the above connection interfaces standardized as the RAN specifications will lead to expanded opportunities for vendors to enter new markets and provision of new services through a combination of functions. Some software has been open-sourced as reference implementation, which may reduce development costs and lead to the development of related software.

Table 1-1 Major connection interfaces defined in 3GPP and O-RAN ALLIANCE

Interface name	**Applicable location**	**Function, etc.**
A1	Between Non-RT RIC and Near-RT RIC	Policy management ML model management, etc.
E2	Between Near-RT RIC and E2 Node	Provision of Near-RT RIC services
O1	SMO and other nodes	Coordination of the whole
O2	SMO and O-Cloud	Communication between SMO and the cloud
Open fronthaul	Between O-DU and O-RU	Communication between parent and child stations
F1	Between gNB-CU and gNB-DU	Sharing frequency resources
X2	Between eNBs or between eNB and en-gNB	Communication between base stations
Xn	Between gNBs, between ng-eNBs, or between ng-eNB and gNB	Communication between base stations

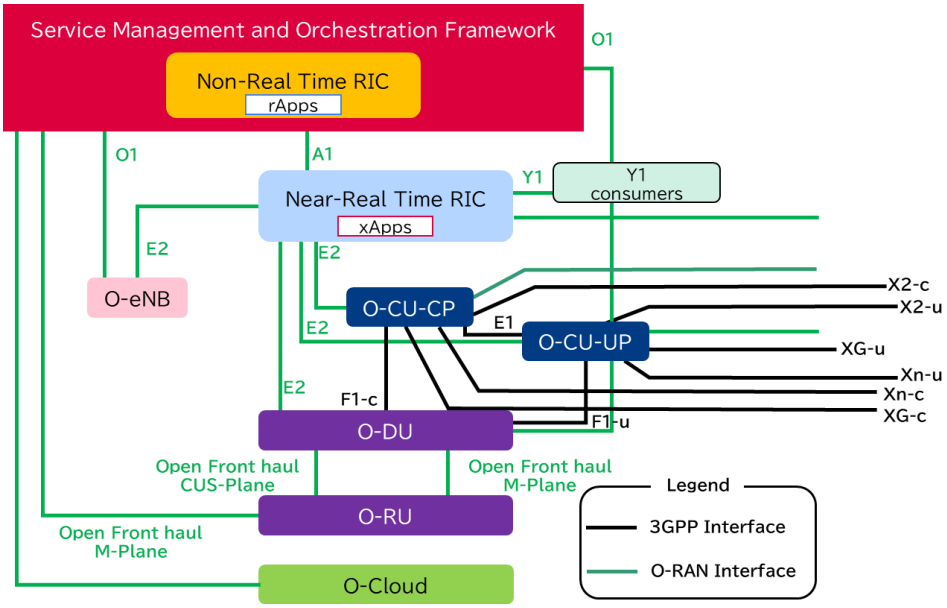

Figure 1-2Overview of O-RAN architecture

Source: Prepared by Mitsubishi Research Institute based on O-RAN ALLIANCE, “O-RAN Architecture Description 8.0 (WG1 Specifications)”

O-RAN ALLIANCE, through the O-RAN Software. Community (OSC), also provides a reference

implementation as Open Source Software (OSS). In April 2019, it launched an open-source community, the O-RAN Software Community (OSC), in collaboration with the Linux Foundation[3]. OSC is continuing its semi-annual release cycle, with its seventh release ("G" release) available as of February 2023[4]. While the AI/ML (Artificial Intelligent/Machine Learning) framework was added as a new project, the projects related to source codes and documentation of deployment procedures were reduced, and there are 12 development projects in total. Such open-source software is expected to contribute to development, testing, and integration initiatives for O-RAN-compliant devices deployed by vendors to commercial networks, as well as to the improvement of software quality.

1.1.2 Virtualization

Open RAN is working to separate the software and hardware platforms of base station equipment. Traditionally, as shown in Figure 1-3, the same vendor had provided a package of software and hardware for DU and CU, which are base station equipment. Open RAN base stations require separation of software and hardware so that MNOs can choose a free mix from different vendors. Particularly with regard to hardware, there are increasing needs for utilization of general-purpose processors and servers, and these needs can be met by selecting a free mix.

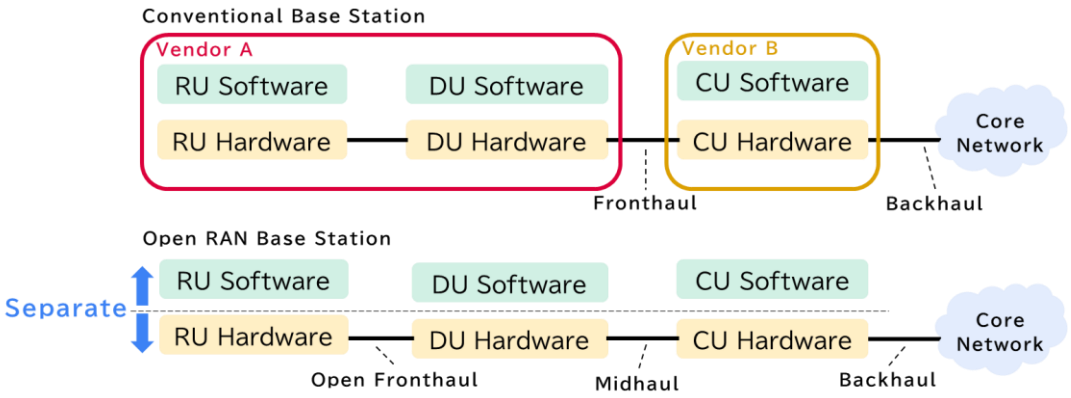

Figure 1-3Separation of software and hardware in Open RAN

Source: Prepared by Mitsubishi Research Institute based on KDDI CORPORATION's presentation material for the second meeting of the Open RAN Promotion Subcommittee

In addition, a virtualization technology to separate some network functions previously realized by RAN hardware and implement them as software has been worked on as vRAN (Virtual Radio Access Network). This improves the virtualization and availability of hardware, enables flexible allocation of resources required for services to the communication capacity, which had previously been designed on the basis of the peak time and the average, and enables the network slicing function to flexibly control the communication bandwidth for each service, thereby providing benefits including the quality required for each service and the avoidance of congestion. As shown in Figure 1-4, the O-RAN ALLIANCE looks ahead to the deployment of "Virtualization" and "cloud" technology through virtualization technology to the configuration of base stations with open interfaces, with the goal of increasing the flexibility of RAN and the speed of product

[3] https://o-ran-sc.org/ Retrieved on March 19, 2024
[4] https://wiki.o-ran-sc.org/display/REL/G+Release Retrieved on March 19, 2024

deployment.

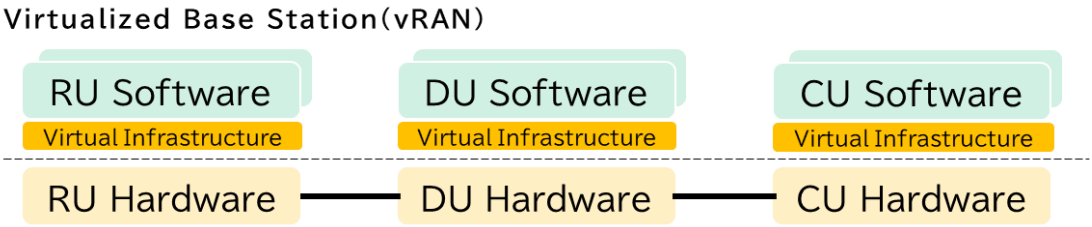

Figure 1-4Virtualization in Open RAN base stations

Source: Prepared by Mitsubishi Research Institute based on KDDI CORPORATION's presentation material for the second meeting of the Open RAN Promotion Subcommittee

WG6 of O-RAN ALLIANCE is discussing the standardization of virtualization and orchestration in Open RAN. The objective is to separate hardware and software in the RAN Intelligent Controller (RIC), O-RAN Central Unit (O-CU), O-RAN Distributed Unit (O-DU), and O-RAN Radio Unit (O-RU), and to deploy software components on the virtualized (cloud) infrastructure of the general-purpose server architecture with the dedicated programmable acceleration function. WG6 collectively recognized these configurations as a virtualization infrastructure and defines it as O-Cloud. O-Cloud can be illustrated as in Figure 1-5. Cloud Stack, open-source software for building and managing a cloud, is built on a general-purpose server equipped with FPGA cards and GPU. This is also an architecture where the Acceleration Abstraction Layer (AAL), an acceleration abstraction technology, is placed between CPU and the accelerator on the general-purpose server, making it possible to use accelerator functions implemented differently in O-DU and other functions. The four specific requirements for O-Cloud are:

1. The Cloud Platform is a set of hardware and software components that provide cloud computing capabilities to4 execute RAN network functions.
2. The Cloud Platform hardware includes computing, networking and storage components, and may also include various acceleration technologies required by the RAN network functions to meet their performance objectives.
3. The Cloud Platform software exposes open and well-defined APIs that enable the management of the entire life cycle for network functions.
4. The Cloud Platform software is decoupled from the Cloud Platform hardware (i.e., it can typically be sourced from different vendors).

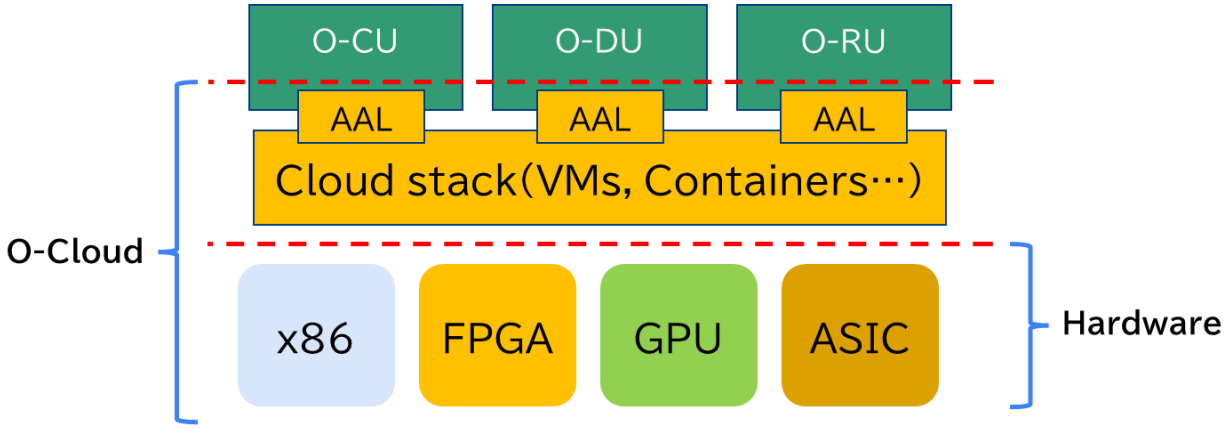

Figure 1-5Concept of O-Cloud

Source: Prepared by Mitsubishi Research Institute based on O-RAN ALLIANCE, "O-RAN Cloud Architecture and Deployment Scenarios for O-RAN Virtualized RAN 4.0 (WG6 Specifications)"

It is also being considered to automatically orchestrate functions separated by this virtualization, with the goal of flexible instantiation and life cycle management. It is assumed that the orchestration function is applied to both the network function virtualization (NFV) architecture, which is deployed and configured as a virtual machine (VM), and the cloud native network function (CNF), which evolved from VNF using containers.

The utilization of virtualization and orchestration functions enables smooth migration of traditional RAN that is made up of RU, DU, and CU from a single vendor. For example, even if the system is already being used in commercial services, the time and expense of hardware replacement can be reduced by separating hardware and software through virtualization and using existing hardware, and the downtime for migration can be minimized by automatically updating the O-RAN ALLIANCE-compliant software by the orchestrator. The downtime for migration can also be reduced through the virtualization of network functions at existing 4G base stations, in addition to 5G base stations. As shown in Figure 1-6, a 4G base station consists of a Remote Radio Head (RRH), which transmits and receives wireless signals, and a Base Band Unit (BBU), which processes baseband digital signals. Some MNOs have consolidated BBU, which had been installed in the 4G base station, into parent stations and virtualized BBU functions as a centralized RAN (C-RAN) architecture[5]. Due to the shift from a network architecture including 4G LTE to 5G standalone-architecture Open RAN, the future mainstream will be the configuration of base stations where functions are virtualized and can be freely arranged, as shown in Figure 1-4.

[5] https://www.juniper.net/jp/ja/research-topics/what-is-open-ran.html Retrieved on March 19, 2024

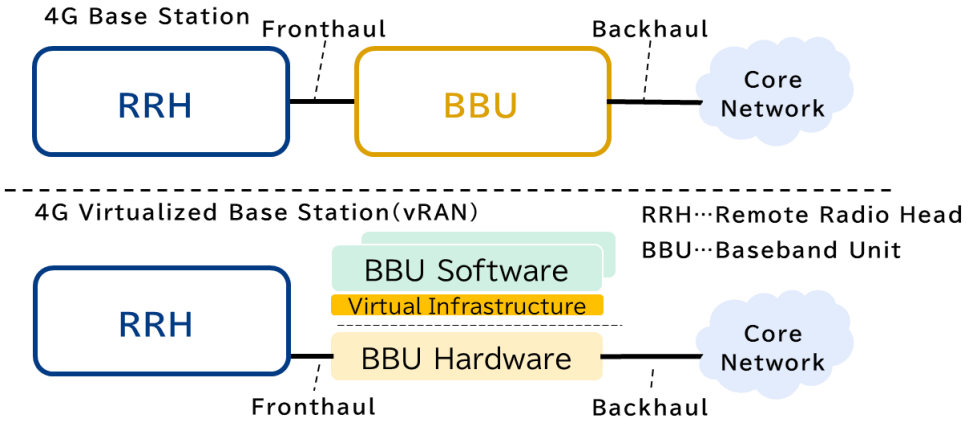

Figure 1-6Virtualization in 4G base stations

Source: Prepared by Mitsubishi Research Institute

Virtualization is expected to bring various benefits during technology development, including CAPEX/OPEX costs, operational resource allocation, and maintenance. These benefits can be divided into general effects from virtualization, effects on MNOs, and effects unique to Open RAN. The general effects from virtualization technologies include lower equipment costs by utilizing general-purpose hardware and quicker service updates and functional enhancements by updating software only. Effects on MNOs include shorter lead time for building equipment, greater flexibility in deployment, and reduced OPEX due to the expansion of remote maintenance coverage and reduction of field operations. Effects unique to Open RAN may include the ability of flexible response, such as the expansion of capacity according to user traffic demand, and the simplified installation of MEC.

There are also problems. Since high-performance processing, which had previously been achieved with dedicated hardware, and real-time support are required, it is assumed that a cloud environment with programmable acceleration functions will be used. In addition, the operation in diverse environments may increase costs of verification to achieve expected performance and costs of maintenance and other operations to maintain performance.

The progress of vendors' development is expected to generate effects while resolving those problems.[6] [7] [8]

1.1.3 Intelligent

To reduce the burden of the construction and operation of RAN on MNOs, there is a need for technologies that automate construction of networks, optimization of operation parameters, and detection and recovery of failures according to traffic and user needs.

In WG2 "Non-real-time RAN Intelligent Controller and A1 Interface" and WG3 "Near-real-time RIC and E2 Interface" of O-RAN ALLIANCE, RIC is defined as a logical node that designs and configures parameters of a base station and automates and optimizes its operation. There are two types of RIC: Non-RT RIC and Near-RT RIC.

Non-RT RIC is part of SMO's function to manage and control the entire RAN function and enable non-

[6] https://www.ednasia.com/o-ran-enables-the-virtualization-of-the-ran-for-5g/ Retrieved on March 19, 2024

[7] https://orandownloadsweb.azurewebsites.net/specifications Retrieved on March 19, 2024
O-RAN.WG6.CADS-v04.00

[8] https://www.nec.com/en/global/solutions/5g/download/pdf/NEC_5G_Open_vRAN_White_Paper.pdf Retrieved on March 19, 2024

real-time (1 second or more) control of E2 nodes through an application called rApps. Specifically, it can reflect configuration parameters optimized for the wireless environment and traffic loads using AI/ML to the E2 node via the O1 interface by the OAM function (Operation Administration and Maintenance). It also collects various data accumulated in the E2 node through the O1 interface. It can generate policies related to the RAN control and inform Near-RT RIC of the policies via the A1 interface.

Near-RT RIC is a function that collects detailed data and takes action on the E2 interface and controls and optimizes the E2 node in near real time (within a second) according to policies communicated by Non-RT RIC. These functions of Near-RT RIC are enabled by an application called xApp.

The AI/ML framework developed and published by OSC adopted by Kubeflow, a framework for automating machine learning workflows such as feature amount engineering of learning data, model learning, and model execution, in order to facilitate the development and operation of machine learning models. Using this framework, xApp can implement, for example, the prediction of Quality of Experience (QoE) of communication by Long Short Term Memory (LSTM), which is one type of deep learning and a method suitable to learning and prediction of time series data[9].

"Intelligent" is expected not only to reduce labor costs and other operation costs required for operation, but also to improve the overall performance of RAN and customer satisfaction. The deployment of AL/ML requires end-to-end performance verification in commercial networks, optimization verification of QoE/Quality of Service (QoS), and performance verification by automatic control of various devices. [10] [11]

1.1.4 Others

Open RAN technology is not only driving "Open," "Virtualization," and "Intelligent," but also generating new effects and ways to use technology. For example, opening has led to the addition of new interfaces that did not exist in traditional RAN, raising security risks. Therefore, WG11 "Security Working Group" of O-RAN ALLIANCE recognizes security problems and the importance of secure RAN, and has identified security requirements and solutions according to rigorous threat modeling and risk analysis. In particular, there is a requirement that the O1 interface, which is a management interface, and the M-plane of the open fronthaul must use TLS or SSH with strong ciphers, mutual authentication with an X.509 certificate, and NACM (The network configuration access control model), which is a robust log that can be integrated with the centralized logging platform of MNOs. Similarly, security specifications have been defined for the A1 and E2 interfaces.

WG11's guidelines also indicate that SBOM must be applied to the software development life cycle of O-RAN. SBOM (Software Bill Of Materials) contains the following minimum elements: Supplier name, Component name, Version of the Component, Other Unique Identifiers, Dependency Relationship, Author of SBOM Data, and Timestamp and so on. Vendors and MNOs are required to regularly check known vulnerability databases by using SBOM to identify potential risks. The application of this SBOM is expected to reduce maintenance and operation costs for security measures.

In addition to SBOM mentioned above, secure SDLC (Software Development Life Cycle: The life cycle

[9] https://wiki.o-ran-sc.org/display/REL/G+Release#GRelease-AIMLFramework(AIMLFW) Retrieved on March 19, 2024
[10] https://journal.ntt.co.jp/article/19554 Retrieved on March 19, 2024
[11] https://orandownloadsweb.azurewebsites.net/specifications Retrieved on March 19, 2024
O-RAN.WG2.Non-RT-RIC-ARCH-TS-v02.01
O-RAN.WG3.RICARCH-v03.00

for developing secure software), where security testing is added to SDLC, is also gaining traction. This idea of security automation has been applied to the software development for O-RAN, and nGRG (The O-RAN next Generation Research Group) is also considering measures to ensure security for the next generation.

In areas other than security, field trials have been conducted for systems using 5G millimeter-wave and other backhaul technologies[12]. Thus, the opening of RAN has contributed to the emergence of new effects and technologies.[13]

[12] https://www.softbank.jp/corp/news/press/sbkk/2022/20220713_01/ Retrieved on March 19, 2024
[13] https://www.docomo.ne.jp/corporate/technology/whitepaper_5g_open_ran/#anc-02 Retrieved on March 19, 2024

2. Open RAN from the perspective of each player

2.1 Open RAN for mobile network operators

The impacts of Open RAN on MNOs are outlined in the following three stages based on the phases in the service delivery process.

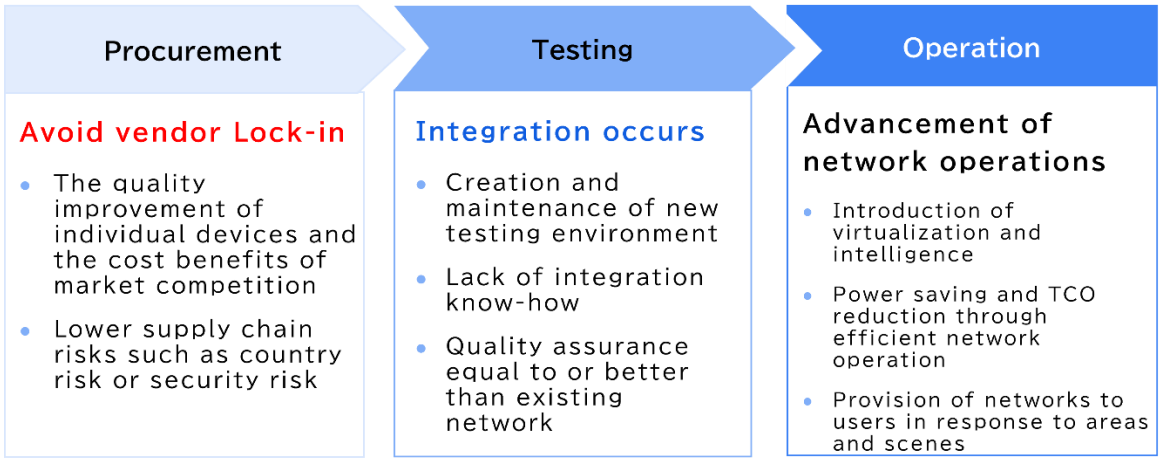

Figure 2-1The service delivery process of MNOs and expected effects of Open RAN

Source: Prepared by Mitsubishi Research Institute

2.1.1 Procurement

The opening of RAN is expected to diversify the network configuration of MNOs, which had previously been based on the configuration of specific vendors. Especially from the perspective of MNOs, it is expected that the improvement of procurement freedom will avoid vendor lock-in and bring about proper market competition. It is expected that if various vendors develop products that take advantage of their respective areas of strength, risks associated with dependence on specific vendors, such as country risk and security risk, can be appropriately controlled, in addition to the quality improvement of individual devices and the cost benefits of market competition.

In fact, from the perspective of cost benefits, Rakuten Mobile, Inc. estimates that the full virtualization, including the diversification of suppliers on the assumption of deploying Open RAN products, will reduce costs by about 30 to 40%[14].

[14] https://b5g.jp/w/wp-content/uploads/pdf/openran_01_rakuten_EN.pdf Retrieved on March 19, 2024

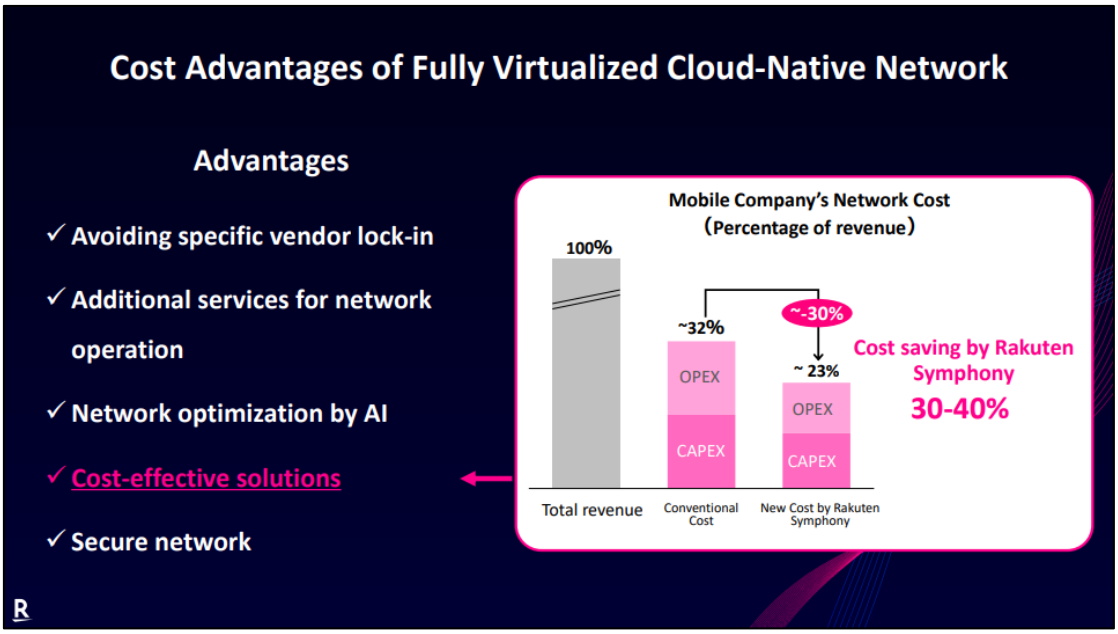

Figure 2-2Examples of cost benefits of full virtualization in Rakuten Mobile, Inc.

Source: Rakuten Mobile, Inc.'s presentation material for the first meeting of the Open RAN Promotion Subcommittee

The cost impacts on MNOs need to be evaluated in terms of TCO that takes into account cost factors such as verification and integration costs in the testing phase, improvement of value added to users due to more intelligent and sophisticated network operations in the operation phase, overall network power saving, and security risk control, instead of evaluation only in the procurement phase. Because required measures vary between the case that a new network is built with Open RAN products and the case where Open RAN products are deployed to an existing network, the impacts on TCO may also vary among individual companies.

These current problems will be clarified and eliminated through accumulation of knowhow by progress of R&D, deployment and operation, and efforts to open RAN should be further accelerated.

2.1.2 Testing

For MNOs that have already built 4G or earlier networks, the establishment of base stations conforming to the Open RAN specifications may cause problems such as performance degradation when integrating with existing networks. There is also a concern that MNOs themselves will increasingly have to choose and take responsibility for achieving product performance and service levels, which had previously been guaranteed by using products from specific vendors[15].

For MNOs that will build a network in the future, it is assumed that the testing in building and commercializing a new network will directly affect the quality of the network to be provided and has significant impact on competitiveness. In doing so, in the case of designing, verifying, and managing the entire network based on the Open RAN specifications without relying on delivery from specific proven vendors, there are concerns about knowhow, limited investment, and human resources, and the speed of network construction[16].

[15] https://b5g.jp/w/wp-content/uploads/pdf/openran_doc02_kddi_EN.pdf Retrieved on March 19, 2024

[16] https://b5g.jp/w/wp-content/uploads/pdf/openran_02_rakuten_EN.pdf Retrieved on March 19, 2024

To resolve these problems, MNOs are currently implementing and considering the construction of their own research environment, and opening their facilities to vendors and their partner companies[17] [18] [19].

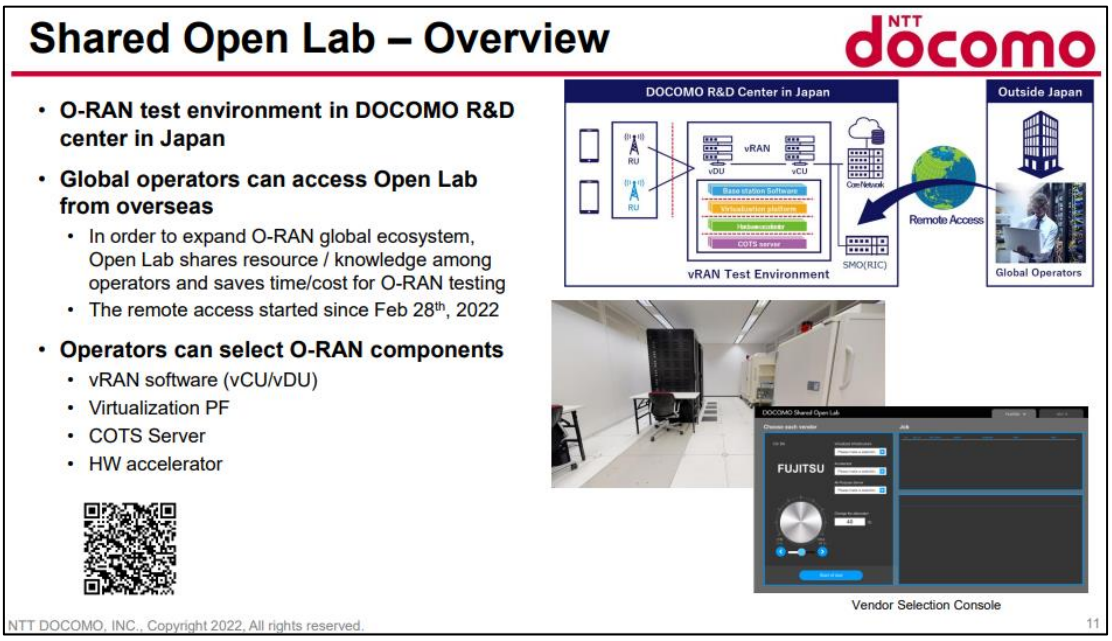

Figure 2-3Shared Open Lab at NTT DOCOMO, Inc.

Source: NTT DOCOMO, Inc.'s presentation material for the first meeting of the Open RAN Promotion Subcommittee

There are also moves to promote the implementation of PoC and the accumulation of knowhow by disclosing joint studies with universities and other research institutions and joint trials with companies in other industries[20]. There is also an opinion that if the verification results of interconnection can be shared among MNOs, a single MNO does not have to have all the capabilities, the testing costs borne by MNOs can be reduced, and the test and verification period can be shortened by sharing problems among multiple MNOs.

For details on the establishment of a test site complying with the O-RAN ALLIANCE specifications by Japanese MNOs, "Japan Open Testing & Integration Centre (OTIC)," see 3.1.3.

2.1.3 Operation

In the operation phase including the inspection and maintenance of devices and the management of performance and security, it is required to appropriately monitor and control base stations configured with products from various vendors and networks that integrate them. MNOs are required to have the ability to integrate diverse vendor devices on their own, or to work closely with vendors with high integration capabilities, or with vendors with the maintenance and operation knowhow that have provided integrated services from deployment to operation. A problem is how to accumulate and use knowhow from design to operation in diverse environments that vary from MNO to MNO.

In addition, the standard specifications of O-RAN ALLIANCE are not sufficient in practical operation as the specifications of RIC/SMO for network control in a dynamic environment of commercial networks. To

[17] https://b5g.jp/w/wp-content/uploads/pdf/openran_01_rakuten_EN.pdf Retrieved on March 19, 2024
[18] https://b5g.jp/w/wp-content/uploads/pdf/openran_02_softbank_EN.pdf Retrieved on March 19, 2024
[19] https://b5g.jp/w/wp-content/uploads/pdf/openran_doc01_docomo.pdf Retrieved on March 19, 2024
[20] https://corp.mobile.rakuten.co.jp/innovation/partner/ Retrieved on March 19, 2024

achieve combinations that meet the requirements demanded by MNOs, vendors also independently provide control functions developed while meeting standard specifications, and mechanisms that allow optimal operation according to the environment[21].

Specific initiatives include those by NTT DOCOMO, Inc. It has adopted the O-RAN specifications for 5G base stations in all of its commercial networks since the launch of 5G pre-service in 2019, and is conducting pre-commercialization trials of a multi-vendor configuration where the O-RAN ALLIANCE specifications are deployed to the X2 interface used to connect 4G base stations with 5G base stations provided by NEC Corporation and Samsung Electronics Co., Ltd and they are currently in commercial operation[22].

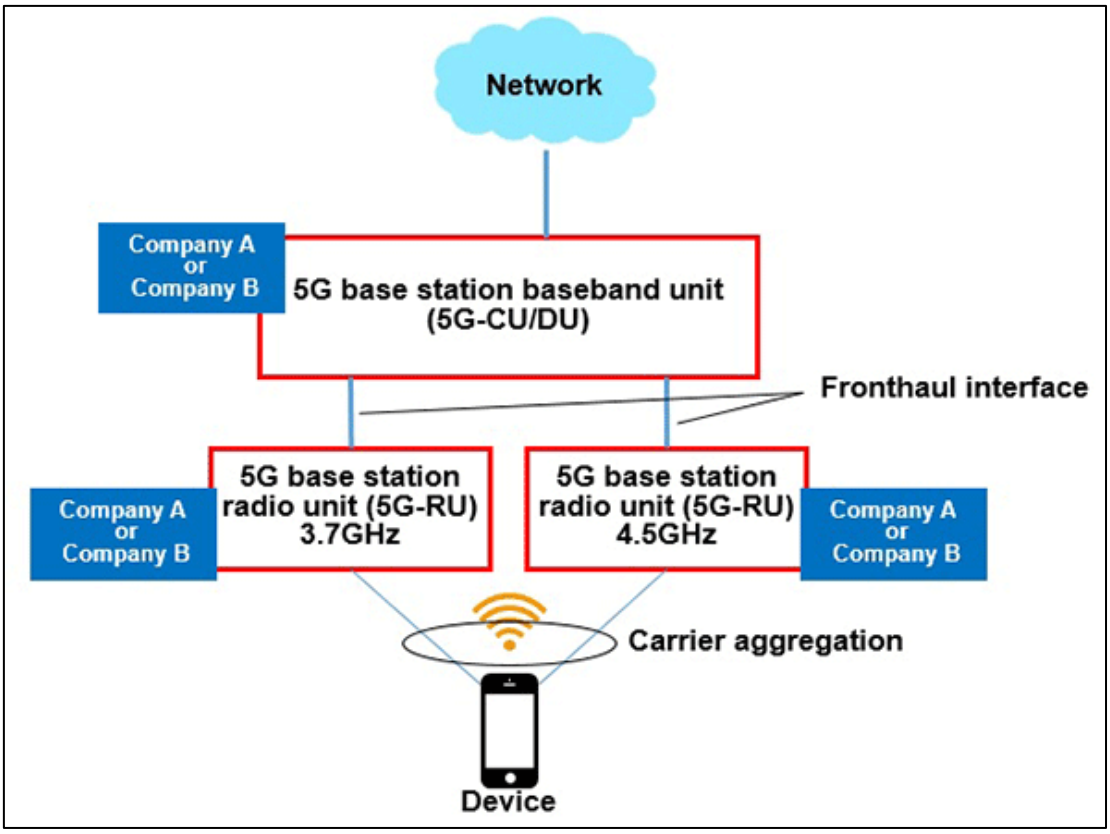

Figure 2-4Example of a multi-vendor configuration in NTT DOCOMO, Inc.

Source: Press release by NTT DOCOMO, Inc.

KDDI CORPORATION began commercial deployment of its virtualized 5G base stations, which became open in 2023. Wireless control devices (CU, DU) provided by Samsung Electronics Co., Ltd. are connected with wireless devices (RU supporting Massive MIMO) from Fujitsu Limited through open interfaces, and the wireless control devices are implemented by using virtualized base station software on a general-purpose server[23].

[21] https://b5g.jp/w/wp-content/uploads/pdf/openran_doc02_nec_EN.pdf Retrieved on March 19, 2024

[22] https://www.docomo.ne.jp/english/info/media_center/pr/2020/0930_00.html Retrieved on March 19, 2024

[23] https://news.kddi.com/kddi/corporate/english/newsrelease/2023/01/24/6509.html Retrieved on March 19, 2024

Figure 2-5 Open virtualized 5G base station commercially deployed by KDDI CORPORATION
Source: Press release by KDDI CORPORATION

The opening of RAN would increase choices of each process, leading to competition for performance and prices among vendors, as well as greater operational freedom. On the other hand, the ability of integration to manage them in an integrated manner is also required at the same time, and companies need to take measures for it. In the deployment of such operational knowhow, Rakuten Symphony is deploying Rakuten Mobile, Inc.'s experience in the mobile business in Japan to overseas operators by developing fully virtualized network platforms and cloud services on its own[24]. Rakuten Symphony claims sales of about 70 billion yen in 2022 and a sales order backlog of about 450 billion yen, and is operating a comprehensive mobile network business by taking advantage of the promotion of Open RAN[25].

2.2 Open RAN for vendors

The impacts of Open RAN on vendors are outlined in the following four stages along the product development process.

[24] https://corp.rakuten.co.jp/news/update/2023/0306_01.html Retrieved on March 19, 2024
[25] https://www.itmedia.co.jp/mobile/articles/2303/06/news094.html Retrieved on March 19, 2024

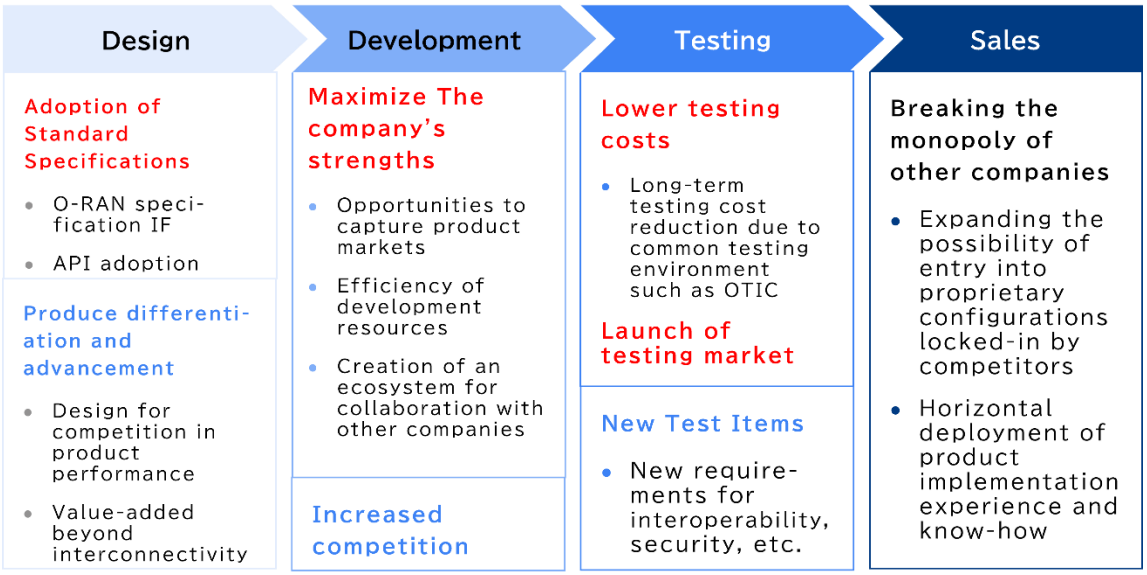

Figure 2-6The product provision process of vendors and expected effects of Open RAN

Source: Prepared by Mitsubishi Research Institute

2.2.1 Design

Previously, product design had assumed connection with in-house or specific vendors' products and devices. Open RAN-compliant products require design conforming to the specifications of standardized interfaces and control software. In the commercial environment of MNOs, devices assuming a multi-vendor environment are expected to be further deployed. For example, there are cases where a company focuses on its in-house design adopting interfaces and APIs conforming to the O-RAN ALLIANCE specifications and using software developed by OSC (O-RAN Software Community) while designing and developing the control on the assumption of deploying RIC apps from different vendors[26]. In addition, more practical approaches include conducting trials with products conforming to the O-RAN specifications through collaboration among proven operators and providing feedback to design and development[27] [28].

[26] https://b5g.jp/w/wp-content/uploads/pdf/openran_doc02_nec_EN.pdf Retrieved on March 19, 2024

[27] https://www.fujitsu.com/global/about/resources/news/press-releases/2023/0124-01.html?_gl=1*1b9ddm7*_ga*MTc4NTA0MDUyMi4xNjgxOTYzODIw*_ga_3XKLQLRH61*MTY4MTk2MzgyMC4xLjAuMTY4MTk2MzgyMS41OS4wLjA Retrieved on March 19, 2024

[28] https://news.kddi.com/kddi/corporate/english/newsrelease/2022/02/18/5896.html Retrieved on March 19, 2024

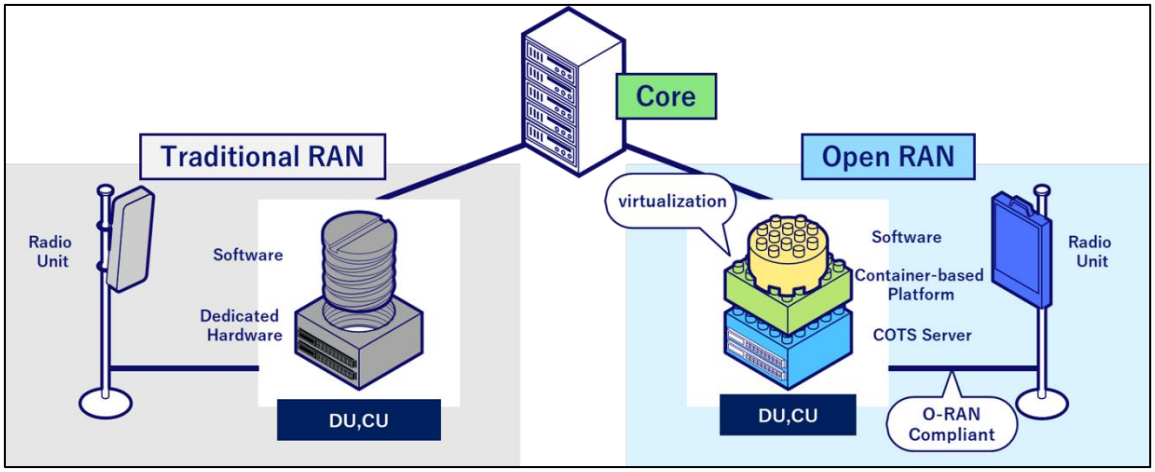

Figure 2-7Traditional base station and 5GSA open virtualized base station

Source: Press releases by KDDI CORPORATION, Samsung Electronics Co., Ltd. and Fujitsu Limited

It is expected that the standardization of interfaces that companies had previously connected in their own way will lead to change in resource allocation after design and to reduction in some costs. Specifically, the performance of internal processing will be improved, and the compatibility with other companies' products will be guaranteed, resulting in the improvement of communication quality performance and cost benefits.

2.2.2 Development

As the development of products conforming to the Open RAN specifications progresses and such products are increasingly adopted in the market, opportunities for entry are expected to increase for new vendors that aim at developing products taking advantage of their strengths and strategically capturing markets[29]. From the perspective of MNOs, it is expected that there will be cost reduction effects due to the market activation through supply of cost-effective products and the technological advance.

With respect to intelligence, which is expected to be promoted by Open RAN in production environments, the development of RIC/SMO in the control area is ahead of other areas. Sophistication is predicted to progress in a way that, for example, a company could plan to provide non-RT RIC while giving way to other companies and third-party products for Near-RT RIC[30]. Other expected initiatives include those where the division of labor with other companies serves as an ecosystem and vendors cooperate with each other to provide total solutions tailored to the needs of MNO customers while centering on the development of products that will be the company's own strength. For that purpose, measures are being considered for smooth adoption and deployment in tandem with the development of products conforming to the Open RAN specifications.

On the other hand, global vendors, which had previously acquired a large share of base stations, are working on the development of both software and hardware in order to provide integration and operation management under the O-RAN specifications as solutions, taking advantage of their expertise in existing

[29] https://b5g.jp/w/wp-content/uploads/pdf/openran_02_softbank_EN.pdf Retrieved on March 19, 2024
[30] https://b5g.jp/w/wp-content/uploads/pdf/openran_doc03_EN.pdf Retrieved on March 19, 2024

base station configurations and the entire network[31][32].

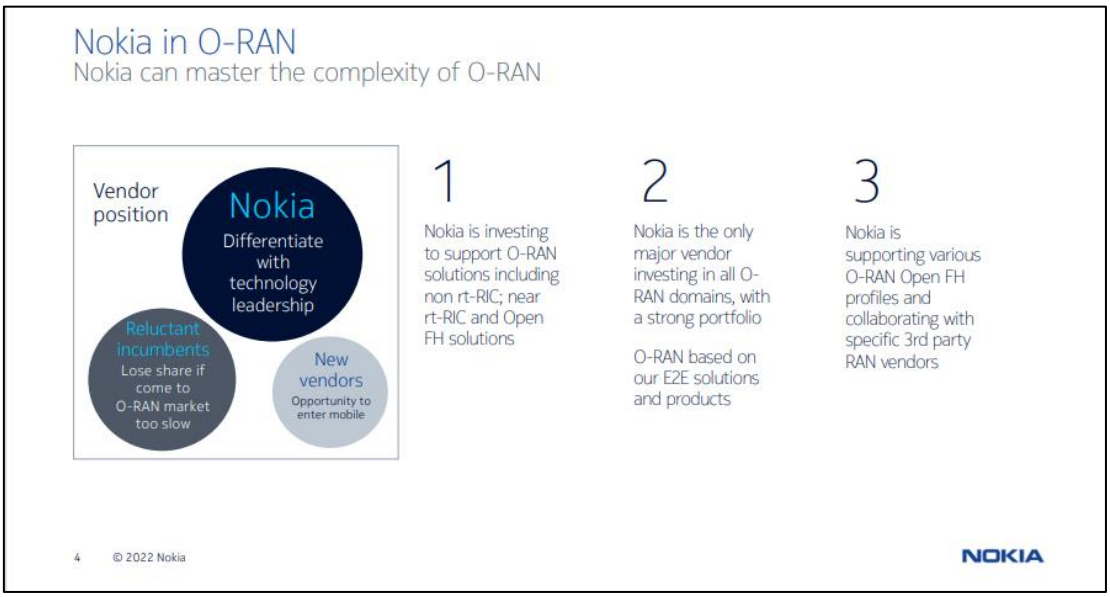

Figure 2-8Initiatives by global vendors

Source: Nokia Solutions and Networks Japan's presentation material for the first meeting of the Open RAN Promotion Subcommittee

In order for Japanese companies to disseminate their own Open RAN products, it is essential to differentiate themselves from global vendors that provide total solutions by expanding into regions of the world where they have not yet expanded, for example. One solution might be the construction of networks with third parties by making the ecosystem mentioned earlier. While global vendors provide networks only with their own products, the development on the assumption of building networks that include products of other companies in accordance with customer needs will eliminate the restriction that the network configuration must be based on a single vendor, and enable responding to component failure using another company's products. In addition, knowhow on integration and operation cultivated during the development and deployment of products on the assumption of such an Open RAN ecosystem may make the provision of new management services feasible. Their realization requires an Open RAN strategy that maximizes the company's own assets in the software and hardware areas, respectively. In this regard, NEC Corporation has positioned the Global 5G Business as the growth business in its Medium-term Management Plan announced in May 2021[33]. It has implemented empowerment for business expansion into the software and service areas, in addition to the global expansion and the development of RU by taking advantage of its experience in supplying base station hardware in Japan.

[31] https://b5g.jp/w/wp-content/uploads/pdf/openran_01_ericson_EN.pdf Retrieved on March 19, 2024
[32] https://b5g.jp/w/wp-content/uploads/pdf/openran_doc01_nokia_EN.pdf Retrieved on March 19, 2024
[33] https://www.nec.com/en/global/ir/pdf/library/210512/210512_02.pdf Retrieved on March 19, 2024

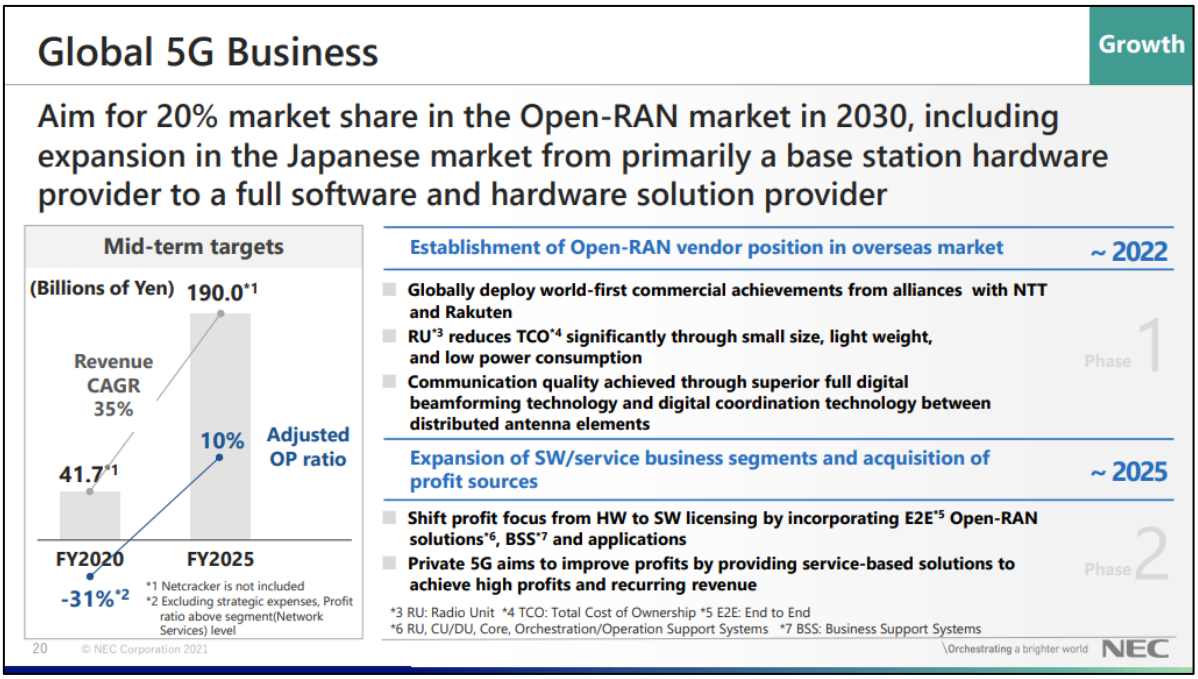

Figure 2-9NEC Corporation's global 5G business and Open RAN

Source: NEC Corporation's document on the 2025 Medium-term Management Plan

2.2.3 Testing

The Open RAN specifications require interoperability testing (IOT) to ensure working in configurations combined with external vendors' products. As mentioned above, vendors are currently establishing places to connect with other companies' products by establishing testing environments and PlugFest, in addition to the establishment of testing environments and OTIC for MNOs[34]. These initiatives and cooperation efforts are expected to result in significant reduction in testing costs. For example, the field trial of a millimeter-wave backhaul system compatible with an O-RAN-compliant open fronthaul jointly conducted by KYOCERA Corporation and SoftBank Corp. "succeeded in 'reducing costs by 1/10 and time by 1/4' (vs. KYOCERA's system)" compared to the previous similar test configurations[35] [36]. Similar cost reductions in the future are expected to enable securing resources for investment in next-generation technologies and human resources. In addition, there may be a benefit that vendors can avoid bearing the cost of interconnection verification each time by using the results of conformance tests and other data as the record of connection with other company's devices.

Furthermore, as Open RAN compliant products become more widely used, the testing equipment market may expand and test environments may be launched. While testing equipment and environments conforming to various standards have been developed in the past, active participation in the standardization process is also expected. For example, the O-RAN ALLIANCE is examining test scenarios, certification and badging

[34] https://b5g.jp/w/wp-content/uploads/pdf/openran_doc01_fujitsu_EN.pdf Retrieved on March 19, 2024
[35] https://b5g.jp/w/wp-content/uploads/pdf/openran_02_softbank_EN.pdf Retrieved on March 19, 2024
[36] https://b5g.jp/w/wp-content/uploads/pdf/openran_doc02_kyocera_EN.pdf Retrieved on March 19, 2024

procedures, and methods to share test results from the standpoint of testing equipment vendors[37].

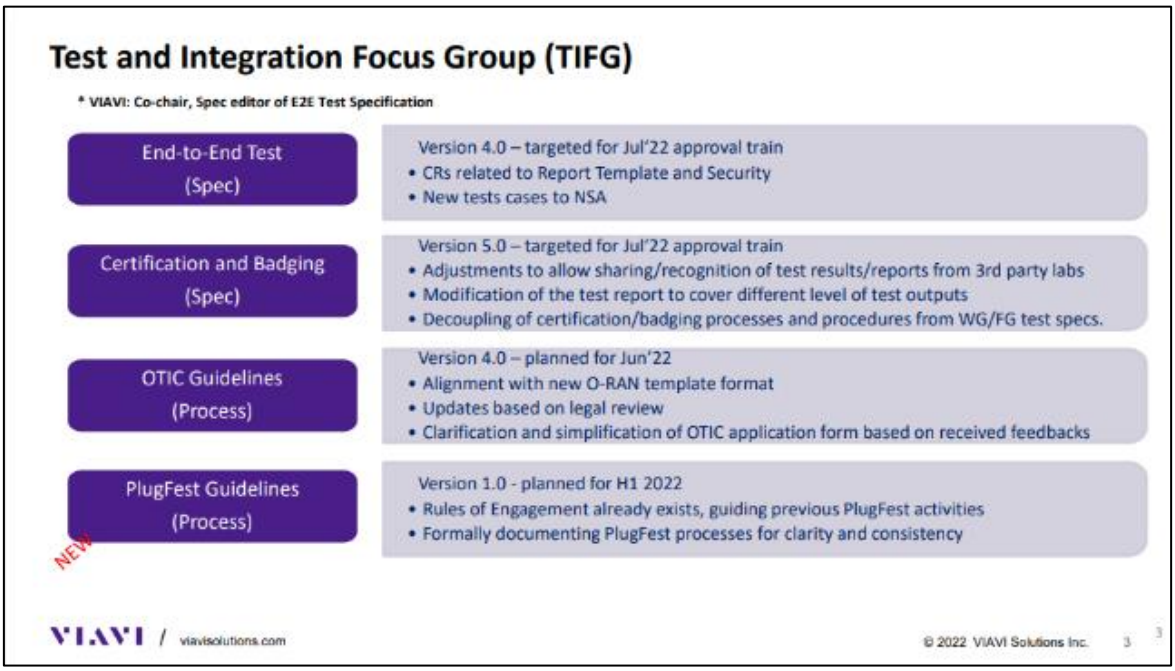

Figure 2-10Activities by O-RAN ALLIANCE TIFG[38]

Source: VIAVI Solutions Inc.'s presentation material for the first meeting of the Open RAN Promotion Subcommittee

VIAVI Solutions Inc. has strengths in fiber cable, wireless and 5G networks, and is working on standardization activities at 3GPP at the same time. Particularly in the wireless area, it has been engaged with end-to-end testing and other activities, taking advantage of its 85% global share of UE simulators. In the future, as Open RAN-compliant products become more widely used, it is assumed new testing markets will be launched, such as connection test between individual devices and performance test, and support for conformance of profiling based on the results of those tests. In Japan, the market is expected to expand through the establishment of Japan OTIC and the readiness of MNOs and vendors for testing, providing opportunities for new entrants.

A system tailored to such segmentation of development trends is also required in Japan. For example, some base station facilities require a certificate of conformance with technical standards. If the separation of RU and CU/DU progresses simultaneously due to the opening of base station configurations, software development companies that have not entered the market may also be required to obtain a certificate of conformance with technical standards and to prepare new testing environments.

2.2.4 Sales and development

As mentioned in 2.2.2, vendors would enjoy more opportunities to enter the market of base stations with proprietary configurations, which had been previously locked into competitors, by strengthening the development of Open RAN-compliant products. There have been cases in which companies took advantage of their branches and other sales networks to carry out trial programs supported by foreign governments or

[37] https://b5g.jp/w/wp-content/uploads/pdf/openran_doc01_viavi_EN.pdf Retrieved on March 19, 2024
[38] https://b5g.jp/w/wp-content/uploads/pdf/openran_doc01_viavi_EN.pdf Retrieved on March 19, 2024

joint trials with overseas MNOs, and actually developed markets as partners with them. At MWC2023, for example, Deutsche Telekom AG announced that it would adopt Fujitsu Limited, in addition to Nokia Corporation and Mavenir Systems, Inc., as a deployment partner for its commercial Open RAN[39]. NEC Corporation has also become a partner of Vodafone Group Plc for its commercial Open RAN, and the promotion of Open RAN has led to its new business[40] [41].

2.3 Open RAN for users

For users using 5G networks, the spread of Open RAN is expected to have the following advantages due to the aforementioned cooperation of MNOs and vendors, respectively[42].

2.3.1 Lower supply chain risks

While the construction of a network that too heavily relies on base stations with configurations that depend on specific countries or companies may lead to cost reduction, it may, in a long run, result in higher costs due to vendor lock-in and increased risks throughout the network supply chain such as country risk. If the moderate distribution and freedom of equipment configurations are ensured by the spread of Open RAN products, users can expect to enjoy benefits from stable network environments and comprehensive benefits from the realization of safe and secure communications.

2.3.2 Improved QoS/QoE

The deployment of the Open RAN specifications is expected to enable consolidation of control within an area through RIC and achieve intelligence that improves the throughput of user requests. Previously, too many users would temporarily use only some frequency bands within an area where services are provided using multiple frequency bands, resulting in some empty frequencies. In addition, when connection to a terminal is handed over between base stations as the user moves, the handover would be delayed due to differences in the frequency bands supported by base stations, which could cause a temporary communication lag. One reason for these problems was that base stations employing different vendors for different frequency bands were mixed in the same or neighboring areas, making it difficult for coordination functions among vendors to work.

To address these problems, the use of RIC for advanced control coordinating base stations is expected to enable to stably ensure higher quality than ever. KDDI CORPORATION broadcast the Tokyo Marathon 2023 using SLA-assured network slicing technology in order to cope with the increasing traffic caused by the expansion of video streaming services, which are increasing particularly in recent years, and the evolution of video technology. These cases illustrate the potential for new network service offerings[43]. If such SLA assurance becomes possible through the realization of communication services that combine advanced control and network slicing through the deployment of RIC, the use of communication is also expected to

[39] https://www.telekom.com/en/media/media-information/archive/first-commercial-open-ran-in-2023-1027618 Retrieved on March 19, 2024
[40] https://www.nec.com/en/press/202011/global_20201130_02.html Retrieved on March 19, 2024
[41] https://www.nec.com/en/press/202106/global_20210615_02.html Retrieved on March 19, 2024
[42] https://ssw.web.docomo.ne.jp/orex/en/ Retrieved on March 19, 2024
[43] https://news.kddi.com/kddi/corporate/newsrelease/2023/03/06/6595.html Retrieved on March 19, 2024

further increase in automobiles and medical care.

In addition, as digital transformation for user companies, there is a need for networks that can flexibly acquire data and quickly change performance and functions. However, in network services for realizing MEC business, which is cited as an example of user needs, it is necessary to first consider applying services for general users to the enterprise area.

As described above, the spread of Open RAN and the technological development accompanying it are expected to contribute to the improvement of sophistication and flexibility of service provision to meet user needs.

2.4 Overall trends in Japan

2.4.1 Status of spread in Japan

Vendors are actively participating in various forums for Open RAN. They are collecting information on benefits and problems with Open RAN, and working on promotion activities. On the other hand, different MNOs have different ideas and initiatives regarding Open RAN depending on their existing facilities, business environment and structure to operate those facilities.

The condition for MNOs to deploy equipment from various vendors is sufficient verification of interconnectivity between base stations and equipment from different vendors. Currently, such verification has been led by MNOs. Therefore, only combinations of limited vendors that have undergone verification led by MNOs supporting Open RAN are currently being used for commercial networks. For example, when multiple devices are from different vendors, the verification of CU, DU and RU, which had previously been unnecessary, is required, creating a new burden for MNOs. MNOs need to take into account verification, integration, and other tasks caused by the separation of nodes under Open RAN, and their problems include the connection verification period and how to reduce costs. This has been a particular problem that MNOs need to solve in adopting Open RAN.

From the vendors' point of view, it does not seem that they have received the original benefit of Open RAN, i.e., "various devices can be freely combined as needed," in such a situation. Therefore, for the further spread of Open RAN, vendor devices need to accumulate sufficient verification records, multiple equipment and devices need to be accepted by MNOs, and the prices and functions of these devices need to be exposed to competition. If these are realized, the optimization would be achieved according to the configuration on the side of MNOs. There are still other problems that need to be solved for widespread use.

2.4.2 New ecosystem

Open RAN has undergone trials and been commercially built in more than 20 countries, including Japan, Europe, the United States, China, Australia and India. Open RAN is estimated to account for 30% of the RAN market by 2025[44], and Vodafone Group Plc and Telefónica, S.A. in Europe announced plans to shift

[44] https://news.mynavi.jp/article/newsinsight-180/ Retrieved on March 19, 2024

20%[45] and 50%[46] to Open RAN, respectively, by 2030. In the United States, Open RAN is being promoted with the government-led Rip & Replace as a trigger. In India, an auction of 5G frequencies was held in July 2022, and the government established the Open RAN lab[47]. A survey showed that 60% of the world's major MNOs are either "planning to work on" or are "actively working on" it[48]. Therefore, the Open RAN market is expected to grow. However, the global market is currently oligopolistic with overseas communication equipment vendors. In other words, it is important for vendors to take advantage of these changes in the ecosystem as a business opportunity and establish their position in the Open RAN market. Therefore, in order for Japanese vendors to be accepted overseas, it is first important that they be accepted by the market as an opportunity to reduce supply chain risks by, for example, demonstrating that their performance and quality are highly evaluated for each function of opened RAN.

For MNOs, the entry of emerging vendors in addition to the existing major base station vendors can promote innovation for opening networks. This will also enable diversification of supply chains and construction of networks by combining solutions, and MNOs are working with related companies based on their strategies. NTT DOCOMO, Inc. is taking a position to actively promote Open RAN and is the global leader in the deployment of Open RAN. In February 2021, NTT DOCOMO, Inc. and global vendors including NEC Corporation and Fujitsu Limited launched OREC (5G Open RAN Ecosystem). OREC strengthened its structure in February 2023 and was developed into a new brand, OREX (Open RAN Ecosystem Experience). To promote the use of Open RAN as soon as possible, it will strengthen cooperation with related companies to support the adoption of Open RAN by MNOs around the world and contribute to the creation of an ecosystem[49].

In addition, Rakuten Mobile, Inc. is actively collaborating with universities by utilizing its Open Innovation Lab Program. Through industry-academia collaboration, it is actively engaged in joint research and development related to Open RAN. Moreover, for collaboration with universities, it is utilizing the Beyond 5G R&D Promotion Project by NICT (National Institute of Information and Communications Technology) to partner with the University of Tokyo and Tokyo Institute of Technology.

In order for Open RAN to become more effective and widespread, more collaborations among companies are required. If Open RAN can be deployed to MNOs' commercial networks quickly and at the right price, it will bring benefits to the telecommunication industry as a whole.

2.4.3 Status of activities of O-RAN ALLIANCE and other standardization organizations

Standardization activities at 3GPP and ITU will remain important for sophistication including basic performance of 5G, incorporation of use cases, and expansion of frequencies. At the same time, there are ongoing fundamental changes, such as the adoption of open architectures for networks based on virtualization through software, on the basis of activities in various forum organizations including O-RAN ALLIANCE. O-RAN ALLIANCE is an industry association founded in February 2018 by the world's 5 major mobile phone companies including NTT DOCOMO, Inc. with the aim of realizing open and intelligent base stations.

[45] https://www.vodafone.co.uk/newscentre/news/openran-in-30-percent-of-vodafone-european-network-by-2030/ Retrieved on March 19, 2024

[46] https://www.telefonica.com/en/communication-room/telefonica-and-nec-to-build-open-ran-live-pilots-in-4-global-markets-as-a-key-milestone-toward-mass-deployment/ Retrieved on March 19, 2024

[47] https://news.mynavi.jp/article/newsinsight-180/ Retrieved on March 19, 2024

[48] NEC Corporation's presentation material in the kick off meeting of Open Ran Promotion Subcommittee

[49] https://ssw.web.docomo.ne.jp/orec/5g_open_ran_ecosystem/pressrelease/pdf/20230227.pdf Retrieved on March 19, 2024

It developed specifications for the interface of signals between base station devices and finalized specifications for the O-RAN fronthaul in March 2019. Today, many MNOs and vendors are participating from around the world, including 4 Japanese MNOs and vendors such as NEC Corporation and Fujitsu Limited. Several working groups are co-chaired by NTT DOCOMO, Inc., KDDI CORPORATION and Rakuten Mobile, Inc. As of February 2023, 322 companies including MNOs and equipment vendors are participating in the organization. Both MNOs and vendors are participating because they feel it advantageous to be able to understand other companies' trends regarding and exchange opinions on Open RAN.

WG	Agenda	Co-chair
1	Use Cases and Overall Architecture	China Mobile Limited, AT&T Inc.
2	Non-Real-Time RAN Intelligent Controller and A1 Interface	China Mobile Limited, KDDI CORPORATION, Telefonaktiebolaget LM Ericsson, Intel Corporation
3	Near-real-time RIC and E2 Interface	Deutsche Telekom AG, China Mobile Limited, Nokia Corporation, Samsung Electronics Co., Ltd.
4	Open Fronthaul Interfaces	NTT DOCOMO, Inc., Verizon Communications Inc., Nokia Corporation, Cisco Systems, Inc.
5	Open F1/W1/E1/X2/Xn Interface	NTT DOCOMO, Inc., Rakuten Mobile, Inc., Telefonaktiebolaget LM Ericsson
6	Cloudification and Orchestration	AT&T Inc., Vodafone Group Plc, Lenovo Corporation, Ciena Corporation
7	White-box Hardware	China Mobile Limited, Verizon Communications Inc., Qualcomm Technologies, Inc., Baicells Technologies Co,.Ltd.
8	Stack Reference Design	China Mobile Limited, AT&T Inc., Intel Corporation, Radisys Corporation
9	Open X-haul Transport	China Mobile Limited, Verizon Communications Inc., VIAVI Solutions Inc.
10	OAM for O-RAN	AT&T Inc., China Mobile Limited, Nokia Corporation
11	Security	Deutsche Telekom AG, Orange、Altiostar Networks, Inc.

Table 2-1Chair of O-RAN ALLIANCE working groups

Source: Prepared by Mitsubishi Research Institute based on O-RAN ALLIANCE's website[50]

2.5 Overseas Trends

2.5.1 The United States

In the United States, efforts are underway to realize Open RAN through collaboration with other countries.

[50] https://public.o-ran.org/ Retrieved on March 19, 2024

In January 2023, a memorandum of understanding (MOU) on promoting Open RAN was signed between Japan and the United States. This aims to facilitate cooperation in information exchange, awareness-raising in third countries, and promoting cooperation in multilateral forums related to 5G and 6G, including Open RAN. Additionally, the Department of Defense, which supports the development of 5G technology by providing military bases as test sites, collaborated with the National Telecommunications and Information Administration (NTIA) in February 2023 to host the "2023 5G Challenge" competition aimed at advancing Open RAN technology[51]. In May of the same year, the United States, Japan, Australia, and India (Quad) jointly published the "Open RAN Security Report". This report, based on the achievements of the Quad's Important and Emerging Technologies Working Group's "Cooperation Memorandum on Diversification of 5G Suppliers and Open RAN", evaluates the advantages, challenges, and potential solutions of Open RAN compared to traditional bulk procurement-based RAN through objective research and analysis, amid growing concerns about Open RAN security in each country[52]. Furthermore, during the U.S.-India summit in June, the two countries agreed to develop Open RAN technology and 5G/6G networks to build a secure and resilient supply chain and achieve global digital inclusion. The "Bharat 6G Alliance" in India and the "Next G Alliance" in the United States, both promoting 6G, announced cooperation in developing next-generation standards[53]. Additionally, in the United States, the Open RAN Policy Coalition, with significant participation from U.S. companies, is conducting standard development and verification activities, similar to the O-RAN Alliance, with the aim of promoting the openness and virtualization of wireless access networks. Japanese companies such as NTT, NEC, Fujitsu, and Rakuten Symphony participate, while Chinese telecommunications companies such as China Mobile and China Telecom do not, indicating a structure of opposition to Huawei and Chinese companies.

2.5.2 Europe

In Europe, there is a push for Open RAN led by telecommunications carriers. In 2021, a recommendation titled "BUILDING AN OPEN RAN ECOSYSTEM FOR EUROPE - for Europe to lead in this essential innovation" was announced by a consortium of MNOs including Deutsche Telekom, Orange, Telecom Italia, Telefonica, and Vodafone to promote the development of an Open RAN ecosystem for Europe[54]. Within this recommendation, five key recommendations were proposed to advance Open RAN in Europe:

- High-level government support for Open RAN.
- Development of a European roadmap for network innovation.
- Provision of incentives and support for Open RAN development in Europe.
- Leadership in Open RAN standardization in Europe.
- Establishment of international partnerships.

Moreover, in 2023, the same consortium issued a white paper focusing on the maturity of Open RAN technology. Pilot trials for Open RAN are planned to increase after 2023, aiming for full commercial

[51] https://www.ntia.gov/press-release/2023/ntia-and-dod-launch-competition-accelerate-adoption-open-ran Retrieved on March 19, 2024
[52] https://www.soumu.go.jp/menu_news/s-news/01tsushin06_02000270.html Retrieved on March 19, 2024
[53] https://www.whitehouse.gov/briefing-room/statements-releases/2023/06/22/joint-statement-from-the-united-states-and-india/ Retrieved on March 19, 2024
[54] https://media.orange.com/c/sirius/building-open-ran-ecosystem-europe-1.pdf Retrieved on March 19, 2024

deployment across Europe by 2025, with emphasis placed on topics such as cybersecurity and energy efficiency[55].

Regarding the promotion structure, there is i4yLab, which aims to promote Open RAN and network decentralization by providing a testbed environment for stakeholders and research institutions. Established with €17 million in funding from the Federal Ministry of Digital and Transport Infrastructure (BMVI) under the leadership of Deutsche Telekom, i4yLab consists of MNOs and vendors such as Vodafone, Telefonica, and Nokia, as well as research institutions including Fraunhofer and Rohde & Schwarz. The lab provides a testbed environment for Open RAN and conducts authentication and other activities[56].

2.5.3 Major vendors's activities

Below is a summary of the business trends related to Open RAN and key alliance/partnership achievements for each major network vendors and software vendors.

- Nokia

Nokia has shown a proactive stance in advancing Open RAN and is participating in initiatives such as the Open RAN Policy Coalition and the O-RAN ALLIANCE[57]. They are also promoting an approach called "Nokia any RAN," which allows mobile operators and other companies to choose hybrid or cloud RAN solutions tailored to their needs, irrespective of their business model[58]. Through the Nokia any RAN approach, they aim to simplify deployment by combining dedicated hybrid RAN solutions with fully cloud-based RAN solutions, enabling deep multi-level separation between the cloud infrastructure layer and the data center (server) hardware layer.

In terms of services, they are deploying AirScale Cloud RAN, which virtualizes the DU and CU and runs them on any cloud server. They offer a portfolio of solutions, including cloud computing hardware platforms (Nokia AirFrame Open Edge) and software, to mobile operators[59].

[55] https://www.telefonica.com/en/communication-room/press-room/major-european-operators-accelerate-progress-on-open-ran/ Retrieved on March 19, 2024
[56] https://www.i14y-lab.com/ Retrieved on March 19, 2024
[57] https://www.nokia.com/networks/radio-access-networks/open-ran/#learn-more Retrieved on March 19, 2024
[58] https://www.nokia.com/networks/mobile-networks/anyran/ Retrieved on March 19, 2024
[59] https://www.nokia.com/about-us/newsroom/articles/open-ran-explained/ Retrieved on March 19, 2024

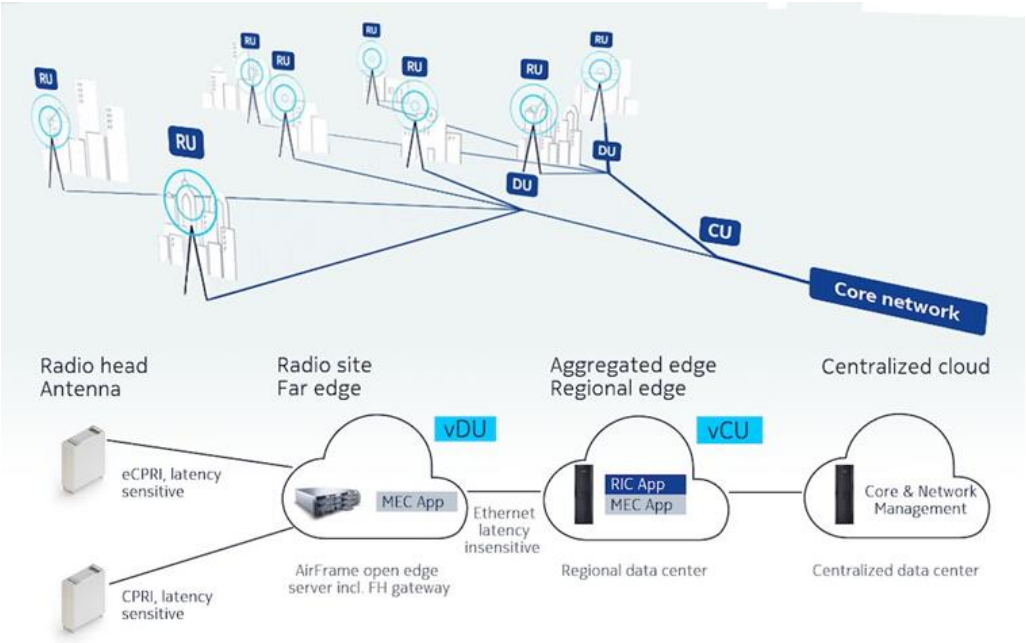

Figure 2-115G AirScale Cloud RAN

In February 26, 2023, Nokia announced that it had entered into a market deployment agreement with one of the world's leading cloud infrastructure and server providers. Additionally, they have been advancing numerous alliances and collaborations. On March 20, 2023, they announced the successful trial of a RIC (RAN Intelligent Controller) software platform in collaboration with AT&T. This platform, built jointly with AT&T, enabled testing of near-real-time RAN Intelligent Controller (near-RT RIC) xApps via the existing E2 interface[60]. They claim that the near-RT RIC xApps utilize artificial intelligence (AI) and machine learning (ML) based optimization algorithms to dynamically enhance RAN performance, enabling RAN optimization tailored to the needs of telecommunications network operators.

- Ericsson

Ericsson actively participates in the O-RAN ALLIANCE, contributing approximately 14% of the total contributions[61]. They collaborate with telecommunications service providers and mobile network suppliers to build a suitable foundation for the openness, innovation, and flexibility of wireless access networks[62].

Additionally, they have established the Ericsson Open Lab, a development environment that provides both virtual and physical lab space environments for fast and interactive collaboration and co-creation with telecommunications service providers and ecosystem partners[63]. They are enhancing cooperation in areas such as Ericsson's Cloud native infrastructure technology, advancements in RAN software on Commercial Off-The-Shelf (COTS) servers and acceleration hardware, machine learning, network automation, and optimization with telecommunications service providers and industry partners. Alliance partners through this lab include telecommunications service providers such as KDDI, Ooredoo, Orange, SoftBank, and Turkcell,

[60] https://www.nokia.com/about-us/news/releases/2023/03/20/nokia-and-att-leverage-advanced-intelligence-of-the-open-ran-compliant-near-real-time-ran-intelligent-controller-with-native-e2-in-successful-trial/ Retrieved on March 19, 2024
[61] https://www.ericsson.com/492301/assets/local/future-technologies/doc/ericsson-in-o-ran-alliance.pdf Retrieved on March 19, 2024
[62] https://www.ericsson.com/en/openness-innovation/open-ran-explained Retrieved on March 19, 2024
[63] https://www.ericsson.com/en/ran/open-lab Retrieved on March 19, 2024

and ecosystem partners such as Intel, NVIDIA, Red Hat, and Wind River.

Furthermore, in collaboration with Intel, they established the Ericsson & Intel Tech Hub on May 30, 2023. This aims to focus on monetizing new business opportunities (such as improving energy efficiency, network performance, reducing time to market, and enabling enterprise applications) by leveraging Intel's computing across multiple generations of Intel Xeon Scalable processors and accelerator technologies to achieve high-density capacity solutions[64].

Additionally, they are seen collaborating with companies like Hewlett Packard Enterprise, DELL, and AMD to improve the technology and interoperability of Cloud RAN. Furthermore, AT&T has announced its partnership with Ericsson to complete the integration of Open RAN sites they operate starting in 2024, aiming to move away from closed proprietary interfaces[65].

- Mavenir Systems

Mavenir offers a portfolio focused on software for Open vRAN. In 2021, they announced the Next-Generation Operations Support Systems (ngOSS). This system is based on OpenAPI and is built with containerization for each functionality group[66].

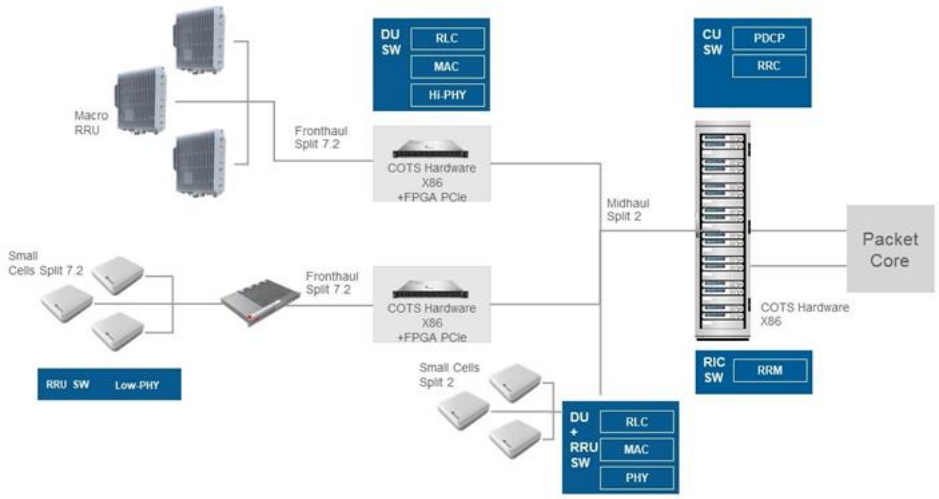

Figure 2-12Next-Generation Operations Support Systems

Mavenir also offers RAN Intelligent Controllers with features such as network performance optimization utilizing machine learning. In 2022, they began providing "Open Beam," a suite of solutions for communication service providers supporting 5G and 4G LTE wireless networks[67]. The characteristics of this solution include:

- Dynamic network capacity expansion and low-load, low-power consumption achieved through RAN intelligence, contributing to improved interoperability across the RAN.
- In February 2023, validation of incorporating AMD's SoC devices into the Open Beam portfolio was

64 https://www.ericsson.com/en/ran/cloud Retrieved on March 19, 2024
65 https://www.ericsson.com/ja/press-releases/2023/12/att-to-accelerate-open-and-interoperable-radio-access-networks-ran-in-the-united-states-through-new-collaboration-with-ericsson Retrieved on March 19, 2024
66 https://www.mavenir.com/portfolio/mavair/radio-access/vran/openran-partner-ecosystem/ Retrieved on March 19, 2024
67 https://www.mavenir.com/portfolio/mavair/openbeam/ Retrieved on March 19, 2024

conducted.

- In February 2024, they announced the next-generation "Green-by-Design" Open Beam™ Massive MIMO radio unit featuring Qualcomm's developed 5G RAN platform, showcasing it at MWC. This significantly improved energy efficiency, especially in high-capacity network environments in urban areas, enhancing network operators' mMIMO uplink performance, minimizing latency, and reducing the required bandwidth for front haul, compared to traditional solutions[68].

Furthermore, Mavenir actively supports MNOs in network deployment. In 2021, they assisted the U.S. emerging carrier DISH in building a 5G network. Mavenir's Open vRAN software is utilized to run the CU on the AWS public cloud, along with the introduction of their messaging service, "Mavenir RCS." In the same year, they also deployed OpenRAN for Vodafone's LTE network in the UK, enabling data communication and VoLTE calls. In 2022, they built an OpenRAN for Orange's 5GSA network (for validation purposes) in France, and in 2023, they partnered with NEC to provide 5G base station equipment with Massive MIMO antennas for Deutsche Telekom in Germany. Additionally, they collaborate with software and hardware vendors to improve interoperability. In 2020, they began collaborating with NEC to provide Open vRAN solutions for the local 5G market in Japan, and in 2021, they started collaborating with NTT Data to provide Open vRAN solutions for communication service providers. In 2023, they partnered with Red Hat to develop Open vRAN solutions that operate on the "OpenShift" application development and operational platform and conducted validation tests of virtualized DU software on Hewlett Packard's servers in the same year.

- NVIDIA

NVIDIA advocates for the integrated platform "NVIDIA AI-on-5G," providing a platform and suite of functionalities that enable the integrated development of IoT and 5G network[69]. Specifically, they leverage their edge servers and GPU acceleration to offer the application framework "NVIDIA Aerial SDK" for building 5G networks. They have also introduced the development platform "Aerial Research Cloud" for virtual construction of 5G and 6G networks, aiming to address challenges in processing power and power consumption[70]. Moreover, at MWC Barcelona 2023, they collaborated with the OSS "Open Air Interface" to deploy networks within event venues, achieving the realization of the entire private network layers in software[71].

[68] https://www.mavenir.com/press-releases/mavenir-unveils-next-generation-green-by-design-openbeam-massive-mimo-radio-powered-by-qualcomm-5g-ran-platforms/ Retrieved on March 19, 2024
[69] https://www.nvidia.com/ja-jp/edge-computing/5g/ Retrieved on March 19, 2024
[70] https://developer.nvidia.com/aerial-sdk Retrieved on March 19, 2024
[71] https://www.virtualexhibition.o-ran.org/classic/generation/2022/category/open-ran-demonstrations/sub/open-interface/246 Retrieved on March 19, 2024

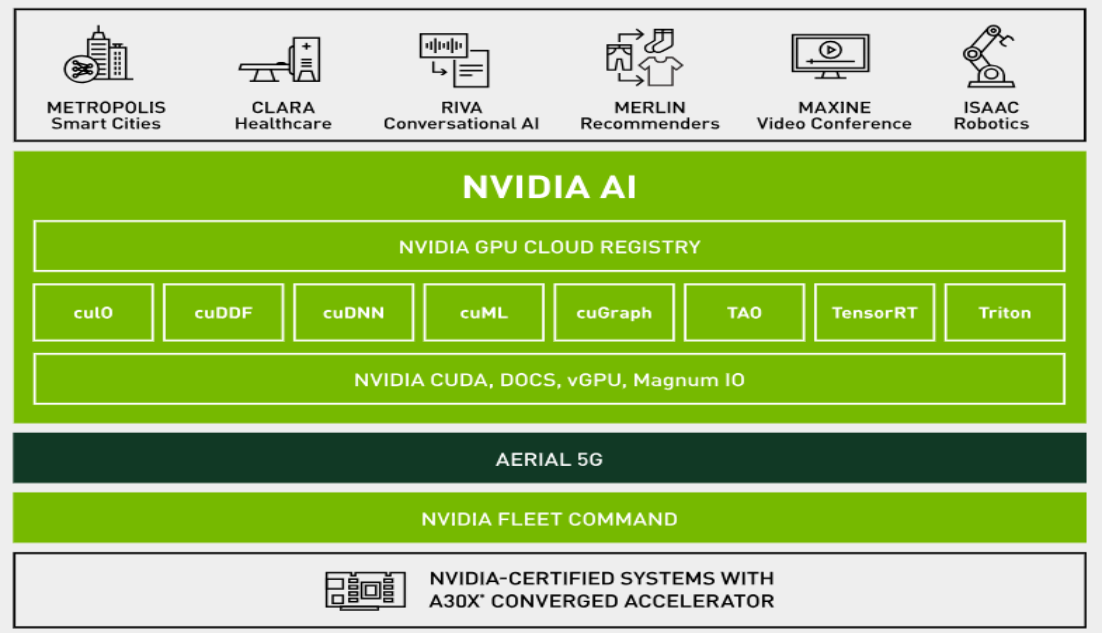

Figure 2-13NVIDIA AI-on-5G

NVIDIA also collaborates with partner companies to establish a platform that integrates IoT development with network development. As an example of collaboration with MNOs, in 2020, they partnered with SoftBank to conduct technical verification of vRAN using "NVIDIA Aerial." They simulated uplink and downlink data communications and measured processing speed and power consumption. As a result, they claim to have met the short processing time required to fully utilize the communication performance of 5G while also reducing power consumption. In 2021, they collaborated with NTT DOCOMO to provide GPU technology to the company's Open RAN package "OREX." In 2023, they announced a collaboration with SoftBank to develop a next-generation platform for building 5G and 6G networks using generative AI. Additionally, in the same year, they announced collaboration with AT&T to conduct network design using the NVIDIA AI platform.

Moreover, they deepen collaboration with IT service providers. In 2021, they announced the establishment of the "AI-on-5G Innovation Lab" with Google Cloud to introduce cloud AI utilizing 5G. Also in the same year, they initiated the development of the "AI-on-5G platform" with Fujitsu, Google Cloud, Mavenir, Radisys, and Wind River to accelerate network construction in smart hospitals, factories, warehouses, and stores.

In 2023, they announced a collaboration with Fujitsu to develop a new 5G vRAN solution combining virtualized CU (vCU) and vDU with NVIDIA GPU technology, and started offering it to customers including MNOs from March[72]. This solution applies NVIDIA's GPU processing engine "NVIDIA A100X" to the physical layer processing of base stations and enables parallel processing of virtualized base stations and edge application GPU hardware resources. It enhances the capacity and processing power of the radio unit (RU) to provide a high-quality communication environment and handle high-load data processing in anticipation of future antenna technology improvements.

[72] https://www.fujitsu.com/global/about/resources/news/press-releases/2023/0220-01.html Retrieved on March 19, 2024

Expected effects of this solution include leveraging GPU resource virtualization to support the provision of new services for enterprise customers, such as AGV (automated guided vehicle) control in manufacturing plants and video delivery using augmented reality (AR) and virtual reality (VR) technologies, by distributing computing resources for high-speed, high-capacity, and low-latency 5G. Additionally, utilizing the high computational power of "A100X" enables the system to handle high-load data processing with simple software updates[73].

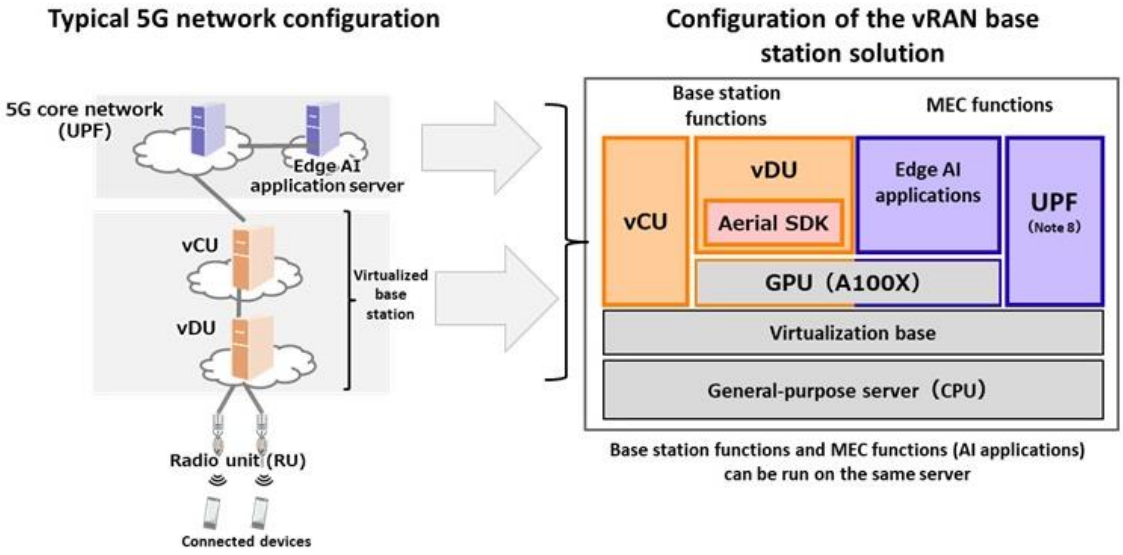

Figure 2-14NVIDIA 5G vRAN solution

[73] https://blogs.nvidia.com/blog/2023/02/27/mwc-ai-on-5g-system/ Retrieved on March 19, 2024

3. Standardization and international collaboration

3.1 Initiatives by companies for standardization and overseas expansion

Five major European MNOs (Deutsche Telekom AG, Orange, TIM S.p.A., Telefónica, S.A., Vodafone Group Plc) concluded an MoU and jointly announced that they will work on security, energy efficiency and other aspects of Open RAN for the full deployment of Open RAN by 2025[74]. MNOs and communication equipment vendors in Japan are working on standardization activities to promote Open RAN and expand the market by collaborating with companies not only in Japan but also in Europe and other regions overseas.

In Japan, the YRP R&D Promotion Committee and MNOs jointly established Japan OTIC in December 2022 to conduct testing and certification based on the standard specifications defined by the O-RAN ALLIANCE. It aims to build an international partnership for the promotion of mutual certification of the Open RAN standard specifications by using this new certification environment.

For overseas expansion, companies have established overseas bases and are actively working to collaborate with MNOs and vendors in relevant countries. By setting up in-house labs that can conduct trials and verification in collaboration with overseas companies, it has been possible to actively work on sharing operational knowhow with overseas vendors and building a track record in connection test.

Standardization makes it possible for vendors to deliver products, at least partially, to overseas MNOs that have built their communication networks with equipment from a single communication equipment vendor, creating new possibilities to acquire customers. It will also enable MNOs in Japan to develop new businesses, such as providing technical knowledge for overseas MNOs to actually deploy Open RAN and support for establishment of verification environments. Although they have been developing communication equipment for their own commercial networks, this will enable them to expand their business in response to requests from overseas MNOs to provide an integrated set of Open RAN base stations.

3.1.1 Mobile network operators' moves to expand overseas

MNOs are seen to be establishing overseas bases and building cooperative relationships with foreign companies utilizing their own labs to promote Open RAN initiatives.

- Rakuten Mobile, Inc.

Rakuten Mobile is advancing the provision and implementation support of Open RAN-related solutions to overseas MNOs, offering services to assist in building Open RAN for overseas carriers by combining solutions from 13 domestic and international vendors with whom they collaborate. In 2020, Rakuten Mobile acquired Innoeye, a US-based company developing a process automation system for cloud platforms, and in the following year, in 2021, it acquired ALTIOSTAR, a US-based company with virtualization technology for BBU. To accelerate its overseas expansion, Rakuten Mobile established subsidiaries in Singapore in 2020, in the US in 2021, and in 2022, it established Rakuten Symphony as a domestic subsidiary[75].

In January 2024, Rakuten Mobile obtained the "O-RAN End-to-End Badge Certification" for 4G/5G NSA

[74] https://www.telefonica.com/en/communication-room/major-european-operators-accelerate-progress-on-open-ran/ Retrieved on March 19, 2024

[75] https://corp.mobile.rakuten.co.jp/news/press/2020/1104_03/ Retrieved on March 19, 2024

from Japan OTIC[76]. In February 2024, it initiated the "Real Open RAN Licensing Program" to accelerate global Open RAN adoption, providing commercial access to CU and DU through an open community subscription model[77]. Also in February 2024, Rakuten Mobile conducted proof-of-concept experiments using "RAN Intelligent Controller" (RIC) powered by AI to manage and control RAN, verifying up to 25% reduction in power consumption in Open RAN networks for both 4G and 5G[78].

Rakuten Mobile has established eight overseas bases and is conducting negotiations with local telecommunications companies and governments[79]. Since 2021, it has supported the network construction of the German emerging carrier 1&1[80], and in the same year, it supported the virtualized network construction on AWS cloud for the US emerging carrier DISH. In the case of DISH's 5G network operation, Rakuten Mobile is implementing service quality management, network monitoring, customer experience aggregation, and automation solutions. Utilizing Rakuten Symphony's network operation system, it monitors the performance of cloud-native network functions in real-time and utilizes the collected data for network optimization, aiming to minimize manual operations and reduce human errors[81].In 2022, Rakuten Mobile announced a collaboration with the US carrier AT&T to incorporate AT&T's capacity planning tool "RANFT" into the wireless access network (RAN) management tool "RAN Commander" as a new feature. Additionally, in the same year, Rakuten Mobile collaborated with the UK-based telecommunications provider Virgin Media O2 and NEC to conduct multi-vendor Open RAN trials in the UK and India. Subsequently, they deployed commercial networks in the UK. Furthermore, Rakuten Mobile made strategic investments and formed partnerships with AST SpaceMobile, a company holding patents related to space communication, to build a satellite communication network in space that would be accessible with existing devices[82].

- NTT DOCOMO, Inc.

NTT Docomo has been deploying base stations combining equipment from multiple vendors since the 4G era, even before the concept of Open RAN emerged. In the domestic deployment of 5G as well, it has introduced base stations based on Open RAN specifications. Collaborating with vendors both domestically and internationally, NTT Docomo offers packaged solutions from vRAN to software and customer services for overseas carriers. The services mentioned above, provided as part of the 5G Open RAN ecosystem until 2021, were rebranded and began to be offered under the brand name "OREX" starting from 2022[83].

NTT Docomo collaborates with various partners to provide each function of OREX. Domestically, they collaborate with Fujitsu, NEC, NTT Data, and internationally with AMD, Dell Technologies, Hewlett Packard, Intel, Mavenir, NVIDIA, Qualcomm, Red Hat, Vmware, and WINDRIVER[84]. In February 2024, they established a joint venture with NEC called "OREX SAI." This joint venture aims to procure all necessary network equipment and software for Open RAN deployment, planning, construction, and maintenance to provide a full-stack service tailored to the needs of telecom operators[85].

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76 https://corp.rakuten.co.jp/news/press/2024/0112_01.html Retrieved on March 19, 2024
77 https://corp.Rakuten.co.jp/news/press/2024/0226_05.html Retrieved on March 19, 2024
78 https://corp.mobile.rakuten.co.jp/news/press/2024/0228_01/ Retrieved on March 19, 2024
79 https://corp.rakuten.co.jp/news/press/2021/0804_03.html Retrieved on March 19, 2024
80 https://corp.mobile.rakuten.co.jp/news/press/2020/1104_03/ Retrieved on March 19, 2024
81 https://corp.rakuten.co.jp/news/press/2021/1124_01.html Retrieved on March 19, 2024
82 https://corp.rakuten.co.jp/news/press/2021/0804_03.html Retrieved on March 19, 2024
83 https://ssw.web.docomo.ne.jp/orex/ Retrieved on March 19, 2024
84 https://ssw.web.docomo.ne.jp/orex/ Retrieved on March 19, 2024
85 https://jpn.nec.com/press/202402/20240226_02.html Retrieved on March 19, 2024

Moreover, NTT Docomo signed a basic agreement with KT Corporation in 2022 to promote Open RAN and is currently conducting demonstrations. They are also conducting Open RAN trials with Smart Communications in the Philippines and agreed to cooperate with Vodafone in the UK to support overseas telecom operators[86]. Additionally, they agreed with DISH Network to evaluate the performance and stability of their equipment in NTT Docomo's "Shared Open Lab." They plan to conduct technical evaluations and consider Open RAN deployment with Singtel in Singapore[87].

NTT Docomo actively participates in standardization organizations. They co-founded the O-RAN ALLIANCE in 2018 and co-chair WG4 (Open Fronthaul) with Verizon, Nokia, and Cisco, as well as WG5 (Open F1/W1/E1/X2/Xn Interface) with Rakuten Mobile and Ericsson. They are also involved in 3GPP and conduct specification reviews for products compliant with O-RAN specifications.

Furthermore, NTT Docomo established a Shared Open Lab in their R&D center in Yokosuka, where testers can freely choose vRAN software, virtualization platforms, general-purpose servers, and hardware accelerators to validate O-RAN products[88]. They share resources with telecom operators worldwide and remotely connect Vodafone's Open RAN research and development center and verification facilities to complement each other's functions. This shared validation facility is estimated to reduce validation costs by up to 40%. Additionally, they aim to jointly build common test scripts with Vodafone to automatically test software and applications[89].

- SoftBank Corp.

As of March 2024, SoftBank does not exhibit significant initiatives for the overseas deployment of Open RAN solutions. However, they are actively engaged in verification processes aimed at the intelligentization of RAN. In February 2024, coinciding with MWC Barcelona 2024, SoftBank announced the establishment of the "AI-RAN Alliance" with companies such as Arm, NVIDIA, and AWS. This alliance focuses on three areas to drive innovation[90]:

- AI for RAN Working Group: Enhancing RAN performance using AI to achieve improvements in wireless efficiency, power consumption reduction, and operational efficiency beyond current constraints.
- AI and RAN Working Group: Facilitating the coexistence of AI applications and RAN workloads to promote efficient resource utilization, optimize equipment investments, and explore revenue opportunities through AI.
- AI on RAN Working Group: Accelerating the development of innovative services for end-users by providing AI services directly from the network edge.

In February 2024, SoftBank collaborated with NEC and Vmware to conduct joint verification of RAN virtualization. They verified the feasibility of RAN modernization through the fusion of "Telecom Cloud," which is the data center resource necessary for mobile network and data transfer functions, enabling Open RAN and the large-scale deployment and management of mobile networks in actual operation[91].

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86 https://www.docomo.ne.jp/binary/pdf/info/news_release/topics_230227_00.pdf Retrieved on March 19, 2024
87 https://www.docomo.ne.jp/info/news_release/2018/02/27_00.html Retrieved on March 19, 2024
88 https://www.docomo.ne.jp/english/info/media_center/pr/2022/0228_00.html Retrieved on March 19, 2024
89 https://ssw.web.docomo.ne.jp/orec/5g_open_ran_ecosystem/pressrelease/20221025.html Retrieved on March 19, 2024
90 https://www.softbank.jp/corp/technology/research/story-event/041/ Retrieved on March 19, 2024
91 https://www.softbank.jp/corp/news/press/sbkk/2024/20240228_01/ Retrieved on March 19, 2024

- KDDI CORPORATION

As of March 2024, KDDI does not exhibit significant initiatives for the overseas deployment of Open RAN solutions. However, they are progressing with the establishment of base stations compliant with the O-RAN standard.

In February 2022, KDDI conducted successful trials of data communication using virtualized base stations for Open 5G SA, in collaboration with Fujitsu, to connect to commercial networks[92].

Additionally, in January 2023, KDDI initiated commercial deployment of OpenRAN (O-RAN) compliant 5G Open Virtual Radio Access Network (Open vRAN) sites in Japan, in collaboration with Samsung Electronics and Fujitsu[93].

3.1.2 Vendors' moves to expand overseas

Communication equipment vendors are aiming not only to expand new related business opportunities generated by the deployment of Open RAN to MNOs in Japan, but also to increase their share of related businesses in overseas markets by taking advantage of their experience in the deployment of devices and software in Japan and their operational knowhow in commercial environments. In overseas markets, they are also trying to expand businesses beyond the deployment of communication equipment. The increased adoption of equipment from communication equipment vendors is expected to bring economies of scale to equipment that uses mass-produced products, thereby lowering unit prices of equipment. This is also a benefit for MNOs. Moreover, communication equipment vendors are looking at opportunities to build cooperative relationships with governments and MNOs overseas, and are focusing on joint verification using products that have been proven in Japan or have high performance.

- NEC Corporation

NEC contributes not only to the deployment of commercial services adopting Open RAN by domestic MNOs but also conducts partnership agreements with overseas MNOs in countries such as the UK, Spain, and Germany, as well as joint verifications with overseas governments[9495]. Furthermore, NEC aims to expand its business to the control unit (CU/DU) and core network upper layers, as well as the software domain, triggered by the provision of radio base stations (RU).

With a policy aimed at achieving a 20% global share in the Open RAN market by 2030, including expanding its business from base station hardware supply in the domestic market to the software domain, NEC's RU devices released in 2021, such as "MB5440," "MB5450," and "MB5460," have been certified as products compliant with TIP OpenRAN requirements. They became the first Massive MIMO units listed on TIP Exchange[96].

In May 2021, NEC provided radio units (RU) for 5G to realize Rakuten Mobile's fully virtualized cloud-native mobile network (RCP)[97]. In June of the same year, it also supplied base stations (RU) equipped with

[92] https://news.kddi.com/kddi/corporate/newsrelease/2022/02/18/5895.html Retrieved on March 19, 2024
[93] https://news.kddi.com/kddi/corporate/newsrelease/2023/01/24/6508.html Retrieved on March 19, 2024
[94] https://www.nikkei.com/article/DGXMZO65443450W0A021C2EAF000/ Retrieved on March 19, 2024
[95] https://jpn.nec.com/press/202109/20210915_01.html Retrieved on March 19, 2024
[96] https://jpn.nec.com/ir/pdf/library/210512/210512_02.pdf Retrieved on March 19, 2024
[97] https://jpn.nec.com/press/202105/20210518_02.html Retrieved on March 19, 2024

Massive MIMO antennas to Deutsche Telekom and Vodafone UK[9899].

In January 2022, NEC acquired Blue Danube Systems[100], a US startup focusing on wireless base station development and AI-based wireless software, and Aspire Technology Unlimited Company[101], an Irish system integrator specializing in building 5G Open RAN systems. In September of the same year, it built an OpenRAN network for Orange's 5GSA validation network in France in collaboration with Mavenir Systems[102].

In February 2024, NEC established a joint venture company with NTT Docomo called "OREX SAI." The company aims to provide full-stack services, including planning, construction, maintenance, and operation of the optimal mobile network tailored to the needs of telecommunication operators by procuring all necessary network equipment and software for Open RAN deployment[103].

- Fujitsu Limited

Fujitsu Limited has also been selected as a partner for Deutsche Telekom AG's deployment of commercial Open RAN in Germany, and will contribute to its expansion in Europe in the future[104]. Both NEC Corporation and Fujitsu Limited are providing equipment to O-RAN Town, a large-scale project planned by Deutsche Telekom AG to provide 4G and 5G services enabled by Open RAN. NEC Corporation is providing RU equipped with a Massive MIMO antenna[105], while Fujitsu Limited is providing O-RU supporting LTE and O-RU supporting 5G NR for the anchor band[106]. Additionally, Fujitsu has started offering globally a virtualized base station solution compatible with 5G, utilizing NVIDIA's GPU solutions. In March 2023, it commenced the global deployment of virtualized base station solutions compatible with 5GSA, equipped with NVIDIA's GPU processing engine "A100X" and acceleration "NVIDIA Aerial SDK"[107]

98 https://jpn.nec.com/press/202106/20210629_03.html Retrieved on March 19, 2024
99 https://jpn.nec.com/press/202106/20210615_02.html Retrieved on March 19, 2024
100 https://jpn.nec.com/press/202201/20220128_01.html Retrieved on March 19, 2024
101 https://jpn.nec.com/press/202207/20220701_01.html Retrieved on March 19, 2024
102 https://jpn.nec.com/press/202209/20220908_01.html Retrieved on March 19, 2024
103 https://jpn.nec.com/press/202402/20240226_02.html Retrieved on March 19, 2024
104 https://www.telekom.com/en/media/media-information/archive/first-commercial-open-ran-in-2023-1027618 Retrieved on March 19, 2024
105 https://jpn.nec.com/press/202106/20210629_03.html Retrieved on March 19, 2024
106 https://www.telekom.com/en/media/media-information/archive/first-commercial-open-ran-in-2023-1027618 Retrieved on March 19, 2024
107 https://pr.fujitsu.com/jp/news/2023/02/20.html Retrieved on March 19, 2024

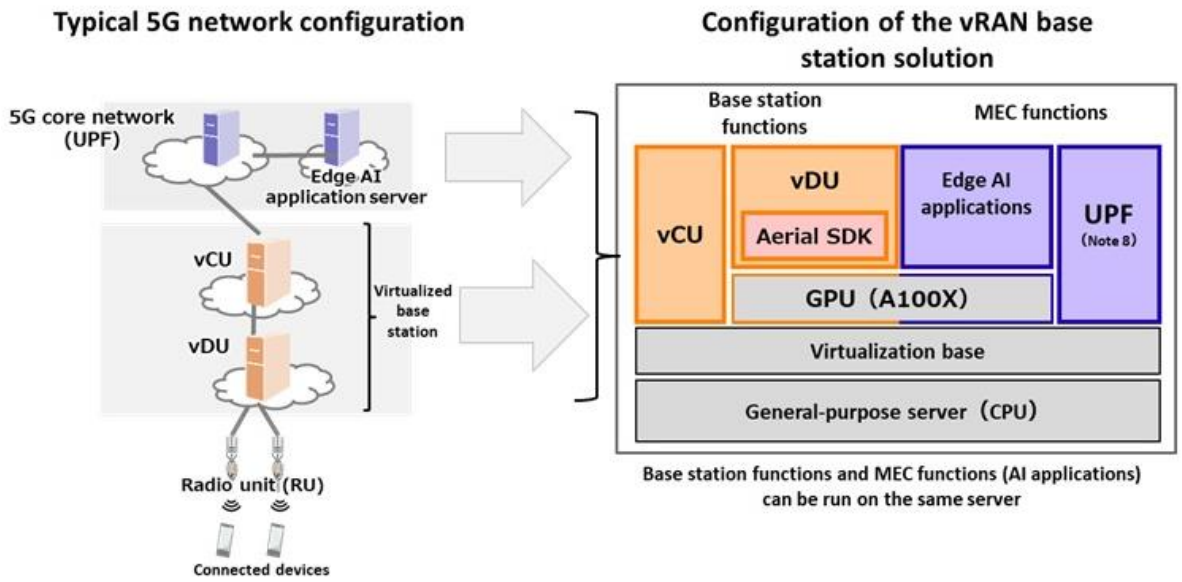

Figure 3-15G vRAN solution

In December 2023, they conducted a proof-of-concept experiment for multi-vendor connections, achieving over a 20% reduction in power consumption compared to conventional methods through AI-driven network operations[108].

In May 2021, Fujitsu's virtualized cloud-native mobile network portfolio, known as Rakuten Communication Platform (RCP), adopted radio units (RUs) for 5G[109]. Then, in September 2022, Fujitsu partnered with Dell Technologies to establish an ecosystem partnership for Open RAN. This collaboration involved not only technical development for Open RAN and the construction of reference architectures but also the interconnection of Fujitsu's "5G Open RAN Interoperability Lab" and Dell Technologies' "Open Telecom Ecosystem Lab," providing a wide-ranging test environment for Open RAN[110].

In February 2023, Fujitsu was selected as a multi-vendor deployment partner for wireless base stations at Deutsche Telekom starting that year[111]. Subsequently, in September, Fujitsu delivered Fujitsu-manufactured 5G virtualized base stations compliant with O-RAN ALLIANCE standards for NTT Docomo's commercial 5G network services. Furthermore, in December, Fujitsu was chosen as one of the suppliers for AT&T's commercial Open RAN[112].

3.1.3 Activities of Japan OTIC and Expectations for the Future

The YRP R&D Promotion Committee, NTT DOCOMO, Inc., KDDI CORPORATION, SoftBank Corp. and Rakuten Mobile, Inc. launched Japan OTIC at the Yokosuka Research Park in Yokosuka City, Kanagawa Prefecture, on December 20, 2022. Japan OTIC is a base for testing and certification based on the standard specifications of O-RAN ALLIANCE, which are international standards, to enable interconnection of various

[108] https://pr.fujitsu.com/jp/news/2023/12/19.html Retrieved on March 19, 2024
[109] https://corp.mobile.Rakuten.co.jp/news/press/2021/0518_02/ Retrieved on March 19, 2024
[110] https://pr.fujitsu.com/jp/news/2022/09/30.html Retrieved on March 19, 2024
[111] https://pr.fujitsu.com/jp/news/2023/09/27.html Retrieved on March 19, 2024
[112] https://about.att.com/story/2023/commercial-scale-open-radio-access-network.html Retrieved on March 19, 2024

mobile communication devices[113]. While OTIC has also been established in Germany, Spain, the United States, China, and other countries, Japan OTIC is the first in the world to be jointly established and operated by multiple MNOs.

Japan OTIC aims to contribute to the sophistication of the Open RAN specifications by making RAN used in telecommunications businesses open, intelligent, virtualized, and highly secure, and to conduct trials of new technologies, support vendors, and promote implementation under the O-RAN specifications. To achieve them, Japan OTIC provides a neutral and open interoperability verification environment compliant with the Open RAN specifications. It also carries out conformance tests and end-to-end tests and interoperability testing for devices of base stations and other facilities to certify the conformity to the O－RAN specifications, which are international standards. The establishment of a test verification environment in Japan is expected to accelerate overseas expansion. It is also expected that knowledge sharing among companies in Japan and overseas will improve the investment efficiency of companies, and that active collaboration will contribute to the globalization and the realization of a more open, higher-quality, and more secure 5G communication society.

Figure 3-2A lab and equipment at Japan OTIC

Source: YRP R&D Promotion Committee's material for the sixth meeting of the Open RAN Promotion Subcommittee

In June 2023, they awarded the first certification for base station equipment compliant with O-RAN specifications to NEC's product[114]. In January 2024, O-RAN E2E Badges were awarded to five products from NEC, Rakuten Symphony, and Quanta Cloud Technology. Among these, the badge awards for two products marked the world's first issuance of E2E badges for the Non Stand Alone (NSA) mode[115].

Table 3-1 Products certified and awarded badges by Japan OTIC

Certification / Badge ID	Date of issued certificate	Type	Interface under test	RAT under test	Device under test	Vendor name	Model name
JPOT230001	2023/6/15	Certificate	OFH	5G NR	O-RU	NEC Corporation	MB5450
JPOT240001	2024/1/12	E2E Badge	-	5G NR	O-RU	NEC Corporation	MB5420-m5770
JPOT240001	2024/1/12	E2E Badge	-	5G NR	O-DU	Rakuten Symphony	BareBone S5I 2U
						Quanta Cloud Technology	

[113] https://japan-otic.jp/ Retrieved on March 19, 2024
[114] https://japan-otic.jp/wp-content/uploads/2023/06/Japan-OTIC-Press-release230621.pdf Retrieved on March 19, 2024
[115] https://japan-otic.jp/jp-news/742 Retrieved on March 19, 2024

Certification / Badge ID	Date of issued certificate	Type	Interface under test	RAT under test	Device under test	Vendor name	Model name
JPOT240001	2024/1/12	E2E Badge	-	5G NR	O-CU	Rakuten Symphony Quanta Cloud Technology	BareBone D52BQ 2U
JPOT240001	2024/1/12	E2E Badge	-	4G LTE	O-eNB DU	Rakuten Symphony Quanta Cloud Technology	BareBone D52BE 2U
JPOT240001	2024/1/12	E2E Badge	-	4G LTE	O-eNB CU	Rakuten Symphony Quanta Cloud Technology	BareBone D52BE 2U

In 2023, we co-hosted workshops for testing, certification, and other activities related to base station equipment.

Table 3-2 workshops by Japan OTIC

WorkShops	Agenda	Number of participants
The first WS July 14, 2023 Co-hosted with Open RAN Promotion Subcommittee	・Overview of Open RAN, O-RAN Alliance, O-RAN specifications, OTIC, authentication badging, PlugFest, etc. ・Overview of authentication and badging tests, PlugFest results, testing equipment, etc. ・Visit to the Japan OTIC lab and equipment	On-site participants: 50 people Remote participants: 177 people Total: 227 people
The second WS October 12, 2023	Laboratory tour	On-site participants: 36 people
The third WS December 14, 2023 Co-hosted with Open RAN Promotion Subcommittee	PlugFest Fall 2023 ■NTT DOCOMO, Inc. ・Multi-vendor vRAN IOT with Open fronthaul ・RAN Security ・Non-RT RIC with multi-vendor rApps ・vRAN integration (incl. O2dms by Tacker, deploying Tacker as DMS with StarlingX) ■KDDI CORPORATION ・Verification of resource optimization for SLA assurance through RIC ■SoftBank Corp. ・Near-RT RIC A1 Conformance Test ■Rakuten Mobile, Inc. ・RIC A1/E2 Conformance Tests)	Remote participants: 124 people (Webinar)

WorkShops	Agenda	Number of participants
	・Non-RT RIC with rAPPs (Energy Saving - Use cases) ・Energy Saving for O-RU ・Test automation (WG4 O-RU Conformance Test, WG4/WG5 IOT, TIFG E2E)	

PlugFest[116] is a regular event held twice a year in spring and autumn by the O-RAN ALLIANCE, aimed at testing and evaluating the interoperability, specifications, solutions, and other aspects of RAN-related equipment. The O-RAN ALLIANCE recruits hosts and participants (RAN equipment vendors, measurement equipment vendors, etc.) for each region where the event is held. The autumn PlugFest in 2023 was conducted in seven locations worldwide, including one in Japan with the participation of 33 companies, yielding the following results.

- Multi-vendor vRAN IOT with Open Fronthaul, achieving further expansion of Open Fronthaul IOT,
- RIC with rApps, achieving development of Non-RT RIC with multi-vendor rApps, including Energy Savings through O-RU,
- Energy Saving for O-RU, achieving development of O-RU micro sleep / O-DU scheduler optimization,
- Verification of resource optimization for SLA assurance through Non-RT RIC, achieving confirmation of the validity of the inter-cell interference suppression,
- RIC A1/E2 Conformance Tests, achieving Non-RT/Near-RT RIC A1/E2 Conformance Tests with IPv6 support,
- RIC A1 Conformance Test, achieving Near-RT RIC A1 Conformance Test and its automated execution,
- vRAN integration, achieving Multi-vendor vRAN integration,
- O-RAN Security, achieving robustness of Open Fronthaul in all CUSM-Plane, and
- O-RAN Test Automation achieving Automated execution of Conformance/IOT/E2E Test cases and verdict.

3.2 The national government's support for Open RAN

3.2.1 Support for standardization activities

In the "MIC's Global Promotion Action Plan 2025" released by the Ministry of Internal Affairs and Communications in July 2022, "5G centered on Open RAN" was listed in the "10 priority areas requiring enhanced initiatives toward 2025" as measures to support standardization activities by the national government[117]. 3GPP, O-RAN ALLIANCE, and other forums are also proceeding with work to standardize RAN specifications. In order to enhance the international competitiveness of Japanese companies, it is necessary for the national government to promote standardization strategically, taking into account the

[116] https://www.o-ran.org/blog/o-ran-alliance-global-plugfest-fall-2023-initiated-with-100-participating-companies-and-institutions Retrieved on March 19, 2024

[117] https://www.soumu.go.jp/main_content/000842643.pdf Retrieved on March 19, 2024

distinctive strengths of each company, such as what to open and standardize. In order to promote the international expansion of Japanese companies, it is necessary for the national government to provide continuous support to various initiatives by MNOs and vendors in carrying out standardization activities, such as “support for international collaboration” and “support for expansion to overseas markets,” which will be discussed later.

In addition, MNOs and vendors expect that Japan OTIC and the Open RAN Promotion Subcommittee will provide opportunities for collaboration and discussion on testing and other matters with companies in Japan and overseas. This is because the full deployment of Open RAN requires sufficient competitiveness comparable to that of conventional equipment, and because companies, facing many problems to solve, recognize the importance of exchanging views not only internally but also with other companies. Furthermore, in order to incorporate Open RAN-compliant products into existing networks, the compliance with Open RAN is indispensable on the side of products from existing vendors in Japan and overseas that are the destination of connection. Therefore, measures are required to encourage those existing vendors to conform to Open RAN. Measures such as financial support for the development of Open RAN-compliant products and tax incentives for the deployment of Open RAN-compliant products would encourage more active Open RAN initiatives.

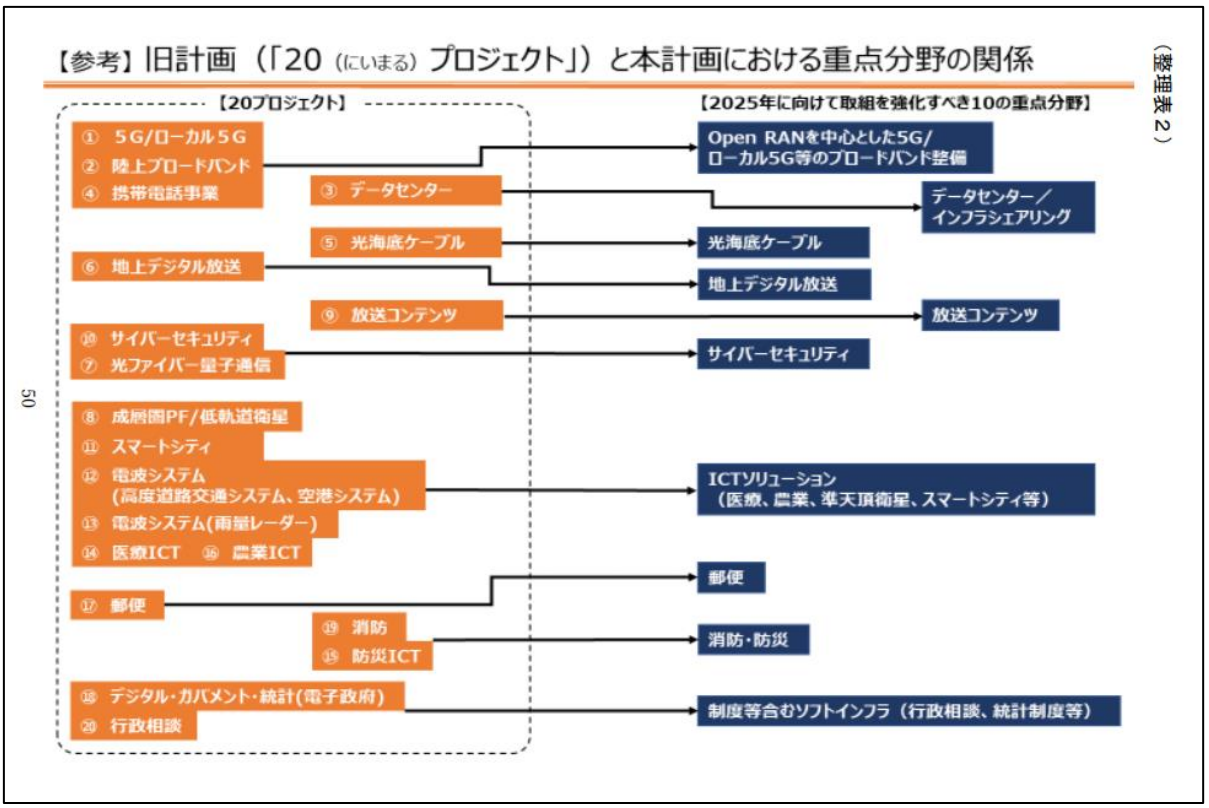

Figure 3-310 priority areas requiring enhanced initiatives toward 2025

Source: The Ministry of Internal Affairs and Communications, “MIC's Global Promotion Action Plan 2025”

		3GPP	O-RAN ALLIANCE	TIP
Member		MNOs, vendors, users	MNOs, vendors	MNOs, vendors
	Major company	Telefonaktiebolaget LM Ericsson, HUAWEI Technologies Co., Ltd., Qualcomm Technologies, Inc., Deutsche Telekom AG, Samsung Electronics Co., Ltd.	AT&T Inc., China Mobile Limited, NTT DOCOMO, Inc.	Vodafone Group Plc
	Japanese companies and organizations (Listed in no particular order)	NTT DOCOMO, Inc., KDDI CORPORATION, SoftBank Corp., Rakuten Mobile, Inc., ANRITSU CORPORATION, ITOCHU Techno-Solutions Corporation, Nippon Telegraph and Telephone Corporation, Japan Broadcasting Corporation, Oki Electric Industry Company, Limited, KYOCERA Corporation, SHARP CORPORATION, Sumitomo Electric Industries, Ltd., Sony Corporation, Sony Group Corporation, DENSO CORPORATION, DKK Co., Ltd., Association of Radio Industries and Businesses, The University of Tokyo, TOYOTA MOTOR CORPORATION, National Institute of Information and Communications Technology, NEC Corporation, Japan Radio Co., Ltd., Fujitsu Limited, FCNT LIMITED, MITSUBISHI ELECTRIC Corporation, Murata Manufacturing Co., Ltd., Panasonic Holdings Corporation	NTT DOCOMO, Inc., KDDI CORPORATION, SoftBank Corp., Rakuten Mobile, Inc., ANRITSU CORPORATION, KYOCERA Corporation, ComWorth Co., Ltd., Sumitomo Electric Industries, Ltd., DKK Co., Ltd., Toshiba Infrastructure Systems & Solutions Corporation, NEC Corporation, NIHON DENGYO KOSAKU CO.,LTD., Hitachi, Ltd., Fujitsu Limited, MegaChips Corporation, Yokosuka Telecom Research Park, Inc., Rakuten Symphony, Renesas Electronics Corporation, YRP R&D Promotion Committee	KDDI CORPORATION, Rakuten Mobile, Inc., ANRITSU CORPORATION, Nippon Telegraph and Telephone Corporation, NTT DATA Corporation, Sumitomo Electric Industries, Ltd., NEC Corporation, Fujitsu Limited, Mitsubishi Electric Research Laboratories

Overview of activities	Formulation of RAN equipment specifications ・Functional separation of CU/DU/RU ・Functional separation of CU-CP/CU-UP ・E1/F1 interface	・Use cases ・Overall architecture ・Optimization and automation of wireless resource control (RIC) ・Open interfaces between RAN devices (A1/E2/O1/O2/fronthaul) ・RAN virtualization	Development, verification and deployment of products conforming to the O-RAN specifications
Output	Specifications documents (released every 1 or 2 years)	Specifications documents Software	Specifications documents Product certification
Number of participants	Over 700	322	Over 500 (total including others than Open RAN WG)
Liaison	O-RAN ALLIANCE	ETSI, TIP, ONF, ONAP	-
Meeting frequency	TSG: 4 times per year WG: 6 times per year	Meetings: 3 times per year	-

Table 3-3 List of RAN opening and virtualization organizations

Source: Prepared by Mitsubishi Research Institute based on each forum site

3.2.2 Support for international collaboration

Recently, digital partnerships among countries have been formed in international frameworks such as QUAD (Japan, the United States, Australia and India), G7 and OECD. For Open RAN, it is also very important for Japanese companies to work toward co-creation with overseas partners by utilizing the frameworks of those inter-state digital partnerships. Japanese companies are expected to expand overseas through public-private partnerships.

It is also necessary to create environments in which Japanese companies can continue to be active around the world. The development of young human resources is essential for continuous acquisition of positions, such as the chairperson of various standardization organizations and forums. It is expected that the national government will continue to develop human resources to support the next generation by holding practical seminars and continuously providing opportunities for exchanges with other companies, such as the Open RAN Promotion Subcommittee[118].

3.2.3 Support for expansion to overseas markets

It is hoped that the national government will actively perform top-level sales, such as showcasing Japanese companies' technologies and products when meeting foreign government officials, and will conclude memorandums of understanding on inter-state cooperation to lay the groundwork for promoting Japanese companies to expand overseas. Top-level sales may improve the recognition of Japanese companies' technologies and products, which may promote the selection of Japanese companies' technologies and products as candidates for adoption overseas, leading to expansion of sales channels.

[118] https://www.kantei.go.jp/jp/singi/titeki2/tyousakai/cycle/dai6/6siryou3.pdf Retrieved on March 19, 2024

One example is initiatives by Japan and the United Kingdom. In March 2022, the Department for Digital, Culture, Media and Sport of the U.K., the Ministry of Internal Affairs and Communications, the Digital Agency and the Ministry of Economy, Trade and Industry of Japan launched the "Telecommunications Supplier Diversification Collaboration Framework[119]." The framework states that "We will explore opportunities to cooperate on research and development initiatives, with a particular focus on seeking to support the work of industry partners in accelerating the development of interoperable equipment and open interfaces, such as Open RAN[120]" and that specific initiatives will be implemented with the primary purpose of sharing information on research and development. In addition, a memorandum of understanding was concluded between the ministers of India and Japan in 2021[121] to promote cooperation in ICT and other areas. This cooperative relationship includes "Initiatives to identify various problems and share necessary information for the promotion of Beyond 5G, such as the establishment of technology verification environments in anticipation of the deployment of 5G networks using Open RAN technology in India[122]." It is hoped that achievements of using such frameworks will be realized.

By carrying out similar initiatives in other regions of the world in addition to the U.K. and India, the presence of Japanese companies in each region will increase. Beyond demonstrating Japan's technological superiority, if Japanese companies' technologies are used to address diverse social problems in partner countries in collaboration with the partner governments, Japan will actually be able to contribute to the world. In addition to bilateral initiatives by national governments, initiatives led by the national government are expected to be implemented to accelerate the overseas expansion of Japanese companies, such as the "Beyond 5G Ready Showcase" as a presentation to the world using opportunities at the Osaka-Kansai Expo 2025[123].

3.3 Towards the Future Advancement of Open RAN

The Open RAN Promotion Subcommittee was established to share information among companies on trends of Open RAN. More efficient business development is expected if companies provide information on the development of Open RAN products, sales status and problems, and share standardization activities including O-RAN ALLIANCE and trends in overseas markets with each other. Through its activities, it serves as a platform for discussions between government and private companies to make various Open RAN-related technologies in Japan internationally competitive. It also promotes information sharing and collaborative activities among related companies.

As some MNOs begin to adopt Open RAN in part of their networks, advancements in technologies like AI are expected to further enhance its sophistication, leading to broader adoption. The maturity of Open RAN technology is anticipated to not only reduce costs but also facilitate the transition to a distributed network architecture, thereby improving network flexibility. This enables MNOs to construct networks in a manner desired by themselves or end-users, facilitating the provision of a wide range of functions and services, thereby enhancing competitiveness in the market.

Open RAN has the potential to become a key enabling technology not only for 5G but also for next-

[119] https://www.soumu.go.jp/menu_news/s-news/01tsushin08_02000129.html Retrieved on March 19, 2024
[120] https://www.soumu.go.jp/main_content/000797716.pdf Retrieved on March 19, 2024
[121] https://www.soumu.go.jp/menu_news/s-news/01tsushin09_02000115.html Retrieved on March 19, 2024
[122] https://www.soumu.go.jp/main_content/000842643.pdf Retrieved on March 19, 2024
[123] https://www.soumu.go.jp/main_content/000696613.pdf Retrieved on March 19, 2024

generation communication infrastructures like Beyond5G. Therefore, continued research and development efforts and activities to expand the adoption of Open RAN are required. Similar activities are observed in Western countries, where MNOs, vendors, and related manufacturers cooperate to actively implement and promote Open RAN. In Japan, efforts to promote and disseminate Open RAN are already being vigorously pursued, with Japan OTIC playing a central role in conducting tests and certifications based on standard specifications set by the O-RAN ALLIANCE. There is also increasing interest from potential entrants in Open RAN. To maintain the momentum of Open RAN promotion, it is essential to further strengthen collaboration both domestically and internationally, with Japan OTIC serving as a base.

4. Appendix

4.1 Abbreviation List

Abbreviation	Explanation
3GPP	3rd Generation Partner-ship Project
4G	4th Generation
5G	5th Generation
5GC	5G Core network
AAL	Acceleration Abstraction Layer
AI	Artificial Intelligent
AI/ML	Artificial Intelligent/Machine Learning
API	Application Programming Interface
BBU	Base Band Unit
CAPEX	Capital Expense
CNF	Containerized Network Functions
CPU	Central Processing Unit
C-RAN	Centralized RAN
CU	Central Unit
DU	Distributed Unit
E2E	End to End
eNB	evolved NodeB
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
FPGA	Field Programmable Gate Array
gNB	Next Generation NodeB
GPU	Graphics Processing Unit
ICT	Information and Communication Technology
IOT	Inter-Operability Testing
IoT	Internet of Things
ITU	International Telecommunication Union
Japan OTIC	Japan Open Testing & Integration Centre
LSTM	Long Short Term Memory
LTE	Long Term Evolution
MAC	Media Access Control
Massive MIMO	Massive Multiple Input Multiple Output
MEC	Multi-access Edge Computing
ML	Machine Learning
MNO	Mobile Network Operator
NACM	The network configuration access control model
NFV	Network Functions Virtualization
ng-eNB	Next Generation eNodeB
nGRG	The O-RAN next Generation Research Group
NICT	National Institute of Information and Communications Technology

NR	New Radio
NSA	Non-StandAlone
OAM	Operation Administration and Maintenance
O-Cloud	O-RAN Cloud Platform
O-CU	O-RAN Central Unit
O-DU	O-RAN Distributed Unit
O-eNB	O-RAN eNodeB
ONAP	Open Network Automation Platform
ONF	Open Networking Foundation
OPEX	Operating Expense
O-RAN ALLIANCE	Open Radio Access Network Alliance
OREC	5G Open RAN Ecosystem
OREX	Open RAN Ecosystem Experience
O-RU	O-RAN Radio Unit
OSC	O-RAN Software Community
OTIC	Open Testing & Integration Centers
PHY	Physical layer
PoC	Proof of Concept
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
rApp	Non-RT RIC Application
RF	Radio Frequency
RIC	RAN Intelligent Controller
RLC	Radio Link Control
RRH	Remote Radio Head
RU	Radio Unit
SBOM	Software Bill of Materials
SDLC	Software Development Life Cycle
SLA	Service Level Agreement
SMO	Service Management and Orchestration
SSH	The Secure Shell
TCO	Total Cost of Ownership
TIP	Telecom Infra Project
TLS	Transport Layer Security
TSG	Technical Specification Group
UE	User Equipment
VM	Virtual Machine
VNF	Virtual Network Function
vRAN	virtual Radio Access Network
WG	Working Group
xApp	Near-RT RIC Application

4.2 Activities of Subcommittee

4.2.1 Kickoff Event

(1) Date and time: 16:00～19:00 on Friday, March 18, 2022

(2) Agenda:

1. Opening Remarks
2. Japanese Carriers' Initiatives
   - ・NTT DOCOMO, Inc.
   - ・KDDI CORPORATION
   - ・SoftBank Corp.
   - ・Rakuten Mobile, Inc.
3. Japanese Vendors' Initiatives
   - ・NEC Corporation
   - ・Fujitsu Limited
4. Oversea Carriers' Initiatives
   - ・Deutsche Telekom
   - ・DISH Network
5. Oversea Vendors' Initiatives
   - ・Dell Technologies
   - ・Samsung Electronics
   - ・NVIDIA
   - ・Rakuten Symphony
6. Initiatives on OTIC
   - ・YRP R&D Promotion Committee
   - ・Orange
   - ・Auray Technology
7. Closing

4.2.2 The First Meeting

(1) Date and time: 13:30～16:30 on Friday, July 22, 2022

(2) Agenda:

1. Opening Remarks
2. Presentation by Open RAN Players
   - ・Nokia Solutions and Networks Japan "Openness in Mobile Networks and Nokia's approach"
   - ・Ericsson Japan "Open RAN and Ericsson Engagement"
   - ・Fujitsu Limited "Fujitsu's Open RAN Activities"
   - ・NTT DOCOMO, Inc. "Open-RAN in DOCOMO"
   - ・Rakuten Mobile, Inc. "Background and Status of Open RAN"

・VIAVI Solutions “O-RAN Alliance Trends and Testing & Integration Process”

3. Schedule and Presentation Solicitation(Secretariat)4. Closing Remarks

4.2.3 The Second Meeting

(1)Date and time 15：00～16:45 on Thursday, September 8, 2022

(2)Agenda
1. Opening Remarks
2. Presentation by Open RAN Players
・KDDI CORPORATION “KDDI’s Approach to Open RAN”
・SoftBank Corp.／KYOCERA Corporation “Achievements and Challenges of Open RAN in Demonstrating of Backhaul System utilizing 5G Millimeter-Wave”
・Rakuten Mobile, Inc. “Open RAN Improvement Strategy”
・NEC Corporation “NEC’s Approach to Open RAN”
3. Schedule and Presentation Solicitation(Secretariat)
4. Closing Remarks

4.2.4 The Third Meeting

(1)Date and time 10:00～10:45 on Friday, October 7, 2022

(2)Agenda
1. Opening Remarks
2. Presentation by Open RAN Players
・Hewlett Packard Japan “HPE Approach to O-RAN – Infrastructure Management Solution for 5G O-RAN Roll Out”
3. Schedule and Presentation Solicitation (Secretariat)
4. Closing Remarks

4.2.5 The Fourth Meeting

(1)Date and time 09:00～09:40 on Monday, December 12, 2022

(2)Agenda
1. Opening Remarks
2. Presentation by Open RAN Players
・Fujitsu Limited “Fujitsu's Open RAN Activities”
3. Schedule and Presentation Solicitation (Secretariat)
4. Closing Remarks

4.2.6 The 1st Part of the Fifth Meeting

(1)Date and time 18:30～19:00 on Thursday, January 26, 2023

(2) Agenda
1. Opening Remarks
2. Presentation by Open RAN Players
YRP R&D Promotion Committee ”Japan OTIC”
3. Schedule and Presentation Solicitation (Secretariat)
4. Closing Remarks

4.2.7 The 2nd Part of the Fifth Meeting

(1) Date and time 19:00～19:30 on Thursday, January 26, 2023
(2) Agenda
1. Explanation on the proposed table of contents
2.Question and Answer
3. Exchange of opinions on the proposed table of contents

4.2.8 The Sixth Meeting

(1) Date and time 19:15～20:30 on Monday, February 13, 2023
(2) Agenda
1. Explanation on the report’s table of contents
2. Discussion on the Report

4.2.9 The Seventh Meeting

(1) Date and time 9:00～10:00 on Friday, February 24, 2023
(2) Agenda
1. Explanation on the changes made to the report from the previous meeting
2. Activity Report：discussion

4.2.10 The Eighth Meeting

(1) Date and time 18:00～19:00 on Friday, March 10, 2023
(2) Agenda
Activity Report
・(Inquiry) Activity Report(draft) collections
・(Inquiry) Additional request function/cost/quality/others
・(Question) Reactions to presentations at MWC

4.2.11 The Ninth Meeting (A Work shop co-hosted with Japan OTIC)

(1) Date and time 13:30～16:45 on Friday, July 14, 2023

(2) Agenda
Activity Report
・Overview of Open RAN, O-RAN Alliance, O-RAN specifications, OTIC, authentication badging, PlugFest, etc.

・Overview of authentication and badging tests, PlugFest results, testing equipment, etc.

・Visit to the Japan OTIC lab and equipment

4.2.12 The Tenth Meeting (A Work shop co-hosted with Japan OTIC)

(1) Date and time: 14:00～16:25 on Thursday, December 14, 2023

(2) Agenda: PlugFest Fall 2023

■NTT DOCOMO, Inc.

・Multi-vendor vRAN IOT with Open fronthaul

・RAN Security

・Non-RT RIC with multi-vendor rApps

・vRAN integration (incl. O2dms by Tacker, deploying Tacker as DMS with StarlingX)

■KDDI CORPORATION

・Verification of resource optimization for SLA assurance through RIC

■SoftBank Corp.

・Near-RT RIC A1 Conformance Test

■Rakuten Mobile, Inc.

・RIC A1/E2 Conformance Tests)

・Non-RT RIC with rAPPs (Energy Saving - Use cases)

・Energy Saving for O-RU

・Test automation (WG4 O-RU Conformance Test, WG4/WG5 IOT, TIFG E2E)

4.2.13 The Eleventh Eighth Meeting

(1) Date and time: Tuesday, January 9, 2024 (Email deliberation)

(2) Agenda: Activity Report

・Gathering opinions on update perspectives for the report version 2.0 in FY2023

4.2.14 The Twelfth Eighth Meeting

(1)Date and time	Wednesday, January 31, 2024 (Email deliberation)
(2)Agenda	Activity Report ・(Inquiry)Confirmation of content regarding perspectives on updating the report version 2.0 for FY2023.

4.2.15 The Thirteenth Meeting

(1)Date and time	Thursday, March 21, 2024 (Email deliberation)
(2)Agenda	Activity Report ・(Inquiry)Confirmation and finalization of revisions to the report version 2.0

Open RAN Promotion Subcommittee Activity Report

March 17, 2023 the First Edition
March 29, 2024 the Second Edition

Beyond 5G Promotion Committee
Open RAN Promotion Subcommittee
(Secretariat: NTT DATA INSTITUTE OF MANAGEMENT CONSULTING, Inc.)